"It is probable that the rise in water surface at Collinsville, due to a barrier at the Point San Pablo site with equivalent gate area, would be less than if located at the Army Point site, but it would not be safe to reduce the gate area at Point San Pablo for the reason that extreme tides through the Golden Gate are more effective near the gate as evidenced by the fact that the tide of November 18, 1918, at Presidio, was 0.7 feet higher than that of January 25, 1914, at which time the maximum elevation of water surface at Suisun City was reached.

"At the Army Point and Dillon Point sites the ship locks are considered effective in passing extremely large floods but they are not considered available at the Point San Pablo site because of the greater necessity for keeping the locks open to navigation at that site, even during great floods.

"The effect of a barrier at the Army Point site would be to reduce the tidal volume passing the Golden Gate by less than 8% in comparison with about 35% if it were built at the Point San Pablo site. The occurrence of frequent high tides in the bays due to piling up of water in them as a result of storms on the ocean would be to eliminate through construction of a barrier at any one of the sites investigated. The effect on the elevations of tides below the structure would be to raise them slightly according to the U. S. Coast & Geodetic Survey.

"*Navigation and Bridge Traffic.* Any plan for the control of salinity involving the construction of a dam across the bay or river channels must be coordinated with the requirements of navigation.

"Ship locks are provided in number and size to meet the requirements of the present and immediate future. Provision for ultimate traffic at the time the barrier is constructed does not seem necessary since flood control on the upper rivers will improve to permit the replacement of flood gates by ship locks as the need for them develops. A summary of the operation as it would have occurred on July 6 and 7, 1925, is shown in Table 6-33.

"Although railroad and highway bridges are contemplated in most of the designs they are not regarded as indispensable and are omitted in some in anticipation of indifference on the part of railroad and highway interests toward the opportunities afforded by the barrier. In the studies made it is considered that traffic over them is subject at all times to the convenience to navigation. The bridges are designed to give a vertical channel of 50 feet above high water when in the lowered position and 135 feet when raised. The interruptions to bridge traffic, as they would have been on July 6 and 7, 1925, are summarized in Table 6-40.

"An examination of Plates 2-3 and 2-4, showing depths in San Pablo and Suisun Bays, will indicate the limitations placed upon commerce under present tidal conditions. If the elevation of the water surface above the barrier were maintained at about 2½ feet above mean sea level, a constant depth equivalent to that at mean high tide under present conditions, would be obtained. Uncertain and varying tidal currents would be eliminated above the barrier and they would be reduced in velocity below. The maintenance of a permanent water level would not only be convenient for navigators but would be a material benefit to owners of wharf property above the barrier.

"The farther downstream the barrier is located the more it will interfere with shipping. Locking requirements can be satisfied with least expense at the Army Point site and conditions are most unfavorable at the Point San Pablo site.

"The construction of a barrier at the Point San Pablo site probably would be looked upon with disfavor by the Navy Department for the reason that it would restrict free navigation through San Pablo Bay to the Mare Island Navy Yard by the necessity of passing war vessels through ship locks. This objection does not apply to the Dillon Point, Benicia or Army Point sites.

"*Storage in the Delta Channels and Bays.* For convenience the calculated storage in the tidal prism above each barrier site, between elevations —3.6 and +6.4 U. S. G. S. Datum (0 and 10, U. S. Engineer Datum) has been summarized in Table 7-2, Volume II.

"*Silt.* The problem has been attacked with the idea that any structure that would be detrimental to San Francisco Harbor would be looked upon with disfavor by those in jurisdiction. The investigation has not definitely determined the effect of a barrier upon silting. Conclusions must, therefore, take the form of conjecture until studies more comprehensive than it was possible to make in this investigation have been completed.

"The construction of a barrier at any one of the sites investigated may possibly have a beneficial effect upon the Golden Gate bar rather than detrimental. The movement of silt toward San Francisco Bay will be checked by the construction of a barrier at Army Point, Benicia, or Dillon Point. A beneficial effect upon the Pinole Shoal will result through the construction of a barrier at Army Point or Point San Pablo. The effect upon Pinole Shoal of a barrier at Dillon Point is at present indeterminate, as is also the effect on silting in San Francisco Bay of a barrier at Point San Pablo.

"Whether the scouring action of the tidal current tends to maintain or destroy fixed channels in the bay system remains to be determined. Should shoaling occur it will be comparatively small in amount and the channels can readily be maintained by dredging, perhaps with less effort and expense than without the barrier. Dredged material pumped into the marshes would build them up and improve their fertility.

"*Salinity.* In years of normal river discharge there is no salinity problem in the delta. It is menacing for a few days in the fall only but, considering the marshes surrounding the upper bays and the towns and industrial plants along their shores, the encroachment of salt water presents a serious problem almost every year.

"Conflict between irrigation interests in the upper valleys and in the delta region never will occur in years of large run-off for the reason that in the development of storage the construction of expensive reservoirs to hold the excessive run-off from the drainage area, occurring only once in a number of years, will not be practicable even though sufficient reservoir sites in which to store all of the run-off were available.

"The introduction of salt water into the fresh water lake through the ship locks can not be prevented but means are provided for drawing off this salt water and thereby controlling the salinity of the water up-stream from the barrier.

"Leakage of salt water past the flood gates, although comparatively small in amount, can be prevented by maintaining the water surface above the barrier at a higher elevation than below.

"Deep gates, opening from the bottom, are essential to the successful operation of the barrier for dependence is placed upon them as a means of drawing off the heavier salt water which seeks the deep holes and channels, and for flushing out the reservoir above the barrier.

"Unless fresh water is available for occasional flushing, the reservoir above the barrier will gradually become salty. Flushing can be accomplished quite readily if water is available for that purpose. The studies of water supply, although based on meager data, indicate that in normal years there will be from eleven to twelve million acre feet available for that purpose. In years of deficient water supply there will be little, if any, fresh water available for flushing and the reservoir above the barrier may have to hold over one or more years without flushing.

"*Return Flow.* Return flow will increase with irrigation development in the upper valleys with the result that the salt menace in the delta will be alleviated; but, even though the return flow should increase to the 3500 second feet estimated to be sufficient to act as a natural barrier against encroachment of salt water, the demand for water will be such that it could not be used for that purpose unless it is replaced by water from mountain storage.

"*Control of Salinity by Storage in Mountain Reservoirs.* Salinity in the delta can be controlled through construction of storage reservoirs in the mountains from which water could be released during the season of low river discharge in the amount necessary to act as a natural barrier against invasions of salt water. Mountain storage would be a temporary expedient for the reason that, ultimately, there will be use for all of the available flow from the rivers, and the discharge into Suisun Bay and thence to the ocean, of water sufficient to act as a natural barrier against salt, would be an economic waste. However, storage created in mountain reservoirs constructed mainly for other purposes might be used for some time to control the salinity in the upper bays and delta channels during development of the requirement for full use of the reservoirs for the purpose for which they were primarily constructed, thus deferring the large investment in the salt water barrier.

"*Teredo.* The factor of salinity is one of fundamental importance in the distribution of teredo. The average lethal salinity for teredo navalis, the species to be feared most in the upper bays, has been determined experimentally as 5 parts per 1000; therefore, if the water above the barrier is maintained at a concentration below the limit for irrigation use teredo can not exist there.

"*Fish.* Fishing industries above the barrier, if constructed, should not suffer for the reason that, even though the fish ladder, which is an integral part of the structure, should fail to function, the fish would not be prevented from entering the fresh water reservoir because they would have free accesss to it through the ship locks which, under normal conditions, would be operated many times throughout each day and night.

"*Sewage.* No investigation was made of the effect of the barrier upon sewage, but from investigations made elsewhere it appears that fresh water will be better adapted for receiving sewage than either salt or brackish water since, gallon for gallon, fresh water disposed in a normal manner of more sewage than salt water. It will be best, in this respect, to keep the water above the barrier fresh because the intermittent admission of salt water interferes with bacterial, animal and vegetable growths that effectively aid in taking care of and digesting sewage.

"*Use of Water in Operation of the Barrier.* The seven main sources of loss of fresh water accompanying the operation of the barrier are evaporation from the water surface of the reservoir created; water required for the operation of the ship locks; leakage around the flood gates; water used in operating the fish ladder; and water to supply the requirements of industries, municipalities and possibly irrigation. With the exception of losses past the flood gates and through the fish ladder, which are constant for the same type of structure, the losses increase as the barrier is moved downstream and this factor has an important bearing upon the selection of a site.

"Owing to the increasing difficulty of maintaining the reservoir created by the barrier free from salt water as the water surface is permitted to fall, and because of navigation requirements, it probably will not be advisable to allow the water surface to fall below mean sea level. Likewise, because of the nature of the delta levees and the cost of drainage in that region by pumping, the ultimate maximum allowable water surface for periods of several months' duration may be fixed at 4.0 feet above mean sea level, although later developments may show that this maximum storage level can be increased to 5.0 feet.

"It is not necessary to decide at this time at what elevation the water surface above the barrier should be maintained. To begin with, it should be held at, or a little below, ordinary high tide level. As time goes on the elevation may be raised as experience dictates.

"Water drawn from the fresh water lake for irrigation, domestic and industrial uses, as well as that required in the operation of the ship locks, should be replenished from river flow or mountain storage with the idea of maintaining a constant depth of water for the navigable waterways effected by construction of the barrier. In years of extreme low run-off the water surface could be drawn down to the elevation of mean sea level, or possibly, in an emergency, to the elevation of mean lower water.

"As the water surface behind the barrier is lowered, the cost of maintaining the Delta levee—not considering floods—should become less; the cost of pumping water out of the lake for any use becomes greater; the cost of pumping seepage water would become less; the difficulties of keeping the lake fresh would increase; and the depth of navigable channels affected would become less.

"Ship locks are provided in various sizes in order to economize on the use of fresh water and to prevent entrance into the fresh water lake of larger volumes of salt water than necessary by requiring vessels to use the smallest lock which will accommodate them. Intermediate lock gates are added for the same reason.

"Economy in the use of fresh water in the operation of the ship locks can be effected through the adoption of lock gates divided horizontally at a depth to allow a large portion of the vessels having a shallow craft to pass through the locks without opening the lower half of the gates and it is assumed that this type of construction will be adopted. It is estimated that the resulting annual saving of fresh water, based on an average daily traffic as it was on July 6-7, 1925, would be:

Army Point Site	173,000 Acre Feet
Dillon Point Site	146,000 " "
Point San Pablo Site	295,000 " "

it being assumed that the water surface above the barrier would be maintained at an elevation 2½ feet above mean sea level.

"It will be necessary to flush the reservoir, preferably once each year, to rid it of accumulations of brackish water resulting, principally, through the inability to trap all of the salt water finding its way into the fresh water reservoir from one source or another. The amount of fresh water required cannot be predicted with any degree of accuracy but a study was made of the amount of fresh water available for the operation of the barrier, based upon the assumption that storage in the mountains was well developed. The study is based upon meager data but the results are believed to be indicative.

"From Table 10-13, it is evident that if the maximum height of water surface in the reservoir is restricted to 2½ feet above mean sea level, the water stored in the reservoir thus formed will not be sufficient to operate the barrier at any of the three sites studied during the irrigation season, even in years of heavy run-off, and it will be desirable, therefore, to seek the highest practicable elevation at which to maintain the storage level.

"The shortage due to lack of reservoir capacity increases as the barrier is moved downstream, although the capacity of the reservoir is greater. This is principally due to the greater evaporation, and to the larger requirements of navigation, industries and municipalities.

"As the storage elevation above the barrier is raised the amount of water available for flushing in years of low run-off is decreased. According to Table 10-13, no water would be available in the season 1923-24 for flushing out the reservoir created through construction of a barrier at the Point San Pablo site whether water were impounded to elevation +2.5, +4.0 or +5.0. It appears that, in any case, there would be no flushing water available in 1923-24 if water were stored to elevation +5.0, although in a normal year there would be a large amount available for flushing, regardless of where the barrier is constructed or of the elevation at which the water surface above the barrier is maintained.

"If the above analysis is correct, it may be concluded that since one of the principal objects of the salt water barrier is to conserve fresh water, it will be desirable to maintain the largest practicable storage capacity above the structure. Likewise, it is evident that the farther downstream the location for the barrier is chosen the greater will be the quantity of water required for operation, and the greater will be the shortage during seasons of low run-off. Since the shortage must be supplied from mountain storage in order to maintain sufficient depth for navigation, and to hold the water level at an elevation where the reservoir will not be deluged with salt water whenever the ship locks are opened, it is apparent that consideration of the necessity for conservation of water would require the selection of one of the upstream sites—Army Point, Dillon Point or Benicia, if the latter, upon investigation, is found to be suitable structurally."

Discussion of Young's Report. The summary just given of Young's report gives his main engineering conclusions. As will be seen, the engineering conclusions are as follows:

1. The construction of a salt water barrier is feasible at either San Pablo Point or at one of three sites near the upper end of Carquinez Strait.
2. The barrier can be utilized for both rail and automobile traffic.
3. The cost will depend upon the method of construction. A barrier can be built at Army Point with bridge of 50-foot clearance for $49,800,000;

at Benicia for $46,200,000; at Dillon Point for $44,700,000; at Point San Pablo for $75,200,000.

4. The barrier will pass a flood of 750,000 second feet (larger than any flood measured into Suisun Bay) with an estimated raising of water surface of 0.7 of a foot at the barrier, at Army Point, and about 0.55 of a foot at Collinsville. Water levels in the delta under extreme conditions are estimated to be below elevations of high water computed by Flood Control Engineer of the state. With a barrier at Point San Pablo, the raise in water level would be slightly less than at Army Point.
5. The barrier would effectively handle both water transportation through locks and bridge transportation.
6. The barrier would store fresh water and prevent the encroachment of salinity now taking place every summer.
7. The barrier will prevent teredo from working above its location.
8. The barrier can be operated so as not to be a detriment to the fishing industry.
9. The elevation at which water is maintained above the barrier in summer has not been determined. To begin with it should be held a little below ordinary high tide. This point is discussed in more detail in the following pages.
10. Young makes no determination of the economic features of the barrier, nor does he recommend a site.

Two things in connection with Young's conclusions may be given further consideration: first, that return seepage will increase in quantity and ameliorate conditions in the delta, and, second, that water from the Sacramento river may be temporarily carried across the delta for use in the San Joaquin valley by releasing stored water and without the construction of the salt water barrier.

With reference to the first matter, it has been shown that return seepage in the San Joaquin Valley is being recaptured by the pumping plants on the west side of the valley and there is now no benefit from the return seepage to delta lands in late summer. There is no prospect for increase in return flow, in fact the increase in pumping from wells all over the valley and new pumps along the river will decrease that flow.

In the Sacramento valley similar conditions prevail. It is not certain that return seepage on this stream has reached a maximum, because a large area of land close to the river is not yet regularly irrigated. When this land becomes more intensively farmed, it is to be expected that it will utilize to a great extent this very return water and decrease the net amount which reaches the tidal waters. Return flow, therefore, cannot be depended upon, in either river, to improve salt water conditions in the delta.

As to the second matter, it may be said that so long as the tide ebbs and flows there will be the opportunity for salt water to penetrate the delta, just as far or farther than was the case in dry years since 1917. In 1920, 1924 and 1926, salt water went beyond Three Mile Slough, the principal connection between the Sacramento and the San Joaquin deltas. If water were drawn up the San Joaquin, there would be a greater tendency for salt water to penetrate the delta and be drawn southward. It should be remembered, too, that in dry years released water from storage reservoirs is going to be very difficult to deliver past the large areas of riparian lands. The flow of the rivers will undoubtedly be so low that tides will carry salt water beyond Three Mile Slough. Certainly no dependence can be placed upon this method of carrying water across the delta. The barrier is essential to prevent tidal movements and the encroachments of salt water.

ELEVATION OF WATER ABOVE BARRIER

Objection, from owners of delta land, has been raised to the proposal by Young that levels above the barrier might eventually be raised above mean high tide in order that more water might be stored for use by the towns, irrigated area and industries around the lake above the barrier.

Mr. G. A. Atherton, who is probably as thoroughly acquainted with the delta region as any other person, is authority for the statement that a level of 6.0 feet U. S. E. D. (or 2.4 U. S. G. S.) continuously maintained in summer months is as high as can be safely held against the delta levees under present conditions. According to him, to carry water higher would endanger the levees, would increase seepage and pumping, and therefore add greater maintenance cost to the delta land owner. It should be understood that Mr. Atherton has reference to the delta lands where peat predominates.

The answer to this argument is that the delta lands will be surrounded by salt water unless the barrier is built, but the barrier can, and should, be operated so as to do no damage to these peat areas.

There is some uncertainty as to the exact difference between the datum of the two surveys (U. S. G. S. and U. S. E. D.) and the level of tide as indicated by tide tables. U. S. G. S. elevations refer to mean sea level and are based upon a number of years of observation. U. S. E. D. levels are based theoretically upon mean lower low water but practically are taken as 3.6 feet lower than the U. S. G. S. levels. Tide gage levels are theoretically based upon mean lower low water but practically are referred to the elevation of a point on the Presidio tide gage staff in San Francisco. As near as can be determined, the U. S. E. D. and tide table datum planes are not the same, but the U. S. E. D. datum is about 0.63 feet lower. This figure is not exact, however, and for practical purposes it may be assumed that the two are the same. In the delta region the tidal range varies more in different parts of the delta than this variation between the two systems of measurement.

If water is held at 6.0 U. S. E. D., it will be at less than high tide in the central delta. Here the tide rises to over 7.0 feet two or three times a year, and in times of southwest storms it has risen to over 8.0. In 1907, during the flood, the elevation exceeded 10.3. With water held at 6.0 there will be no menace to levees and comparatively little increase in pumping out of seepage water. Furthermore, this elevation will permit the efficient operation of the barrier, for salt water is higher than 6.0 at the Golden Gate less than one per cent of the time, excluding storm and flood periods.

Any increase in height should be made only if it can be done without menace to the island levees. In storm periods water will be held lower than would naturally occur except in the most extreme floods. Reservoirs which have been constructed on nearly all tributaries of the Sacramento and San Joaquin rivers will undoubtedly have the effect of reducing the peaks of floods, and there is little likelihood of a repetition of the extremes experienced in 1907, at least such extremes will occur less frequently.

On the whole, the delta lands will be better off with the barrier than without it. The one factor of slightly increased pumping with the summer level held at 6.0 will be more than overbalanced by the freedom from the present menace of salt water.

SELECTION OF SITE FOR BARRIER

Mr. Young in his report sets forth the conditions surrounding the locations investigated as sites for the barrier. The following statement compares the two locations—the three sites investigated near the upper end of Carquinez Strait being treated as one:

Water Supply: Tables attached give the estimated quantities of water required for all uses above the barrier. The quantities here given are estimated uses when all area above the barrier is developed and are liberal figures, with an allowance for flushing to remove salt water let in by ship locks and leakage. The figures show that under these conditions the requirements for the full year are:

Point San Pablo	2,024,000	Acre Feet
Army Point	1,160,000	" "
Difference	864,000	" "

For the irrigation period May to September, inclusive, the requirements are:

Point San Pablo	1,236,000	Acre Feet
Army Point	638,000	" "
Difference	598,000	" "

The large difference comes principally from the quantity of water required to operate locks and the increased evaporation in the lower site. In other words, from six to eight hundred thousand acre feet are required to supply the additional unavoidable losses from evaporation and ship lockages in San Pablo Bay.

In the matter of cost, Young's estimates show for a barrier with 50 feet of clearance the following:

Point San Pablo	$75,200,000
Army Point	49,800,000
Difference	$25,400,000

The convenience to other interests is of great importance. The Mare Island Navy Yard is located above Point San Pablo but below Carquinez Strait, naval officers will object to the barrier. On account of the greater number of vessels which pass San Pablo than through the upper end of Carquinez Strait, there will be less objection to the upper site.

Barriers at both sites will serve as bridges. The San Pablo location will replace a ferry now in operation—the upper site in Carquinez Strait will serve both for rail and vehicular traffic and will replace two ferries.

The opportunity to combine the barrier with the Southern Pacific Railroad at Port Costa should not be overlooked. The Railroad Company is contemplating the construction of a bridge to replace the present ferry. If the Army Point-Suisun Point site is selected by the railroad, the barrier can not be built on this site. In some respects this is the most attractive site and until final determination is made of the location, no permit should be given for a bridge across this place.

STORAGE AND RELEASE TO CONTROL SALT WATER

This method of solving the salt water problem has been suggested in several recent publications of the Department of Public Works. Examination in detail of the proposals shows that "salt water control" means the supplying of water of less than 100 parts chlorine per 100,000 to the delta lands. Emmaton on the Sacramento and Jersey Island on the San Joaquin are the limits of control and no suggestion has been made that it is practical to release water to supply Antioch or any of the lower industrial area. This, in fact, leaves out of consideration the area now most seriously damaged.

Studies by the Division of Water Rights based on records including the year 1925 show that to control salinity below 100 parts chlorine per 100,000, the combined flow of the Sacramento at Sacramento and San Joaquin at Vernalis (both points about the head of tide water in late summer) must exceed the following figures:

For control at	Cubic Feet Per Second
Emmaton and Jersey Island	3500
Antioch	5000
Collinsville	5500
O. & A. Ferry	6000

These quantities will depend to some extent upon the months preceding the period when control is desired and will, of course, vary with the diversions below the points of measurement. Furthermore, storage of water above tide level will affect the matter by limiting the distance salt water is forced downstream by spring floods.

To effectively supply these quantities of water will require very large storage capacity in dry years.

In 1924 storage in excess of a million acre feet would have been required to control salinity at the Oakland & Antioch Ferry and 370,000 at Emmaton and Jersey. In 1926 over 500,000 acre feet would have been required at the Oakland & Antioch Ferry and 200,000 acre feet at Emmaton and Jersey. Storage in large amount would be needed about half the years at Emmaton and Jersey and every year for control at the O. & A. Ferry.

The above is under the assumption that storage and diversions in these two valleys do not increase. As shown earlier, this condition has already been violated, for there has never been such increased activity in building storage reservoirs as in the period since 1924. Many reservoirs are planned for construction in the near future. Furthermore, diversions increase every year. Estimates of the quantities required for storage control must therefore be continuously revised upwards.

Release of stored water, to control salinity, will occur in dry parts of the year and to the greatest extent in dry years. To effectively control the right of storage and release, all riparian owners below the reservoir must agree to the arrangement. As the law now stands, the use of such a reservoir may be enjoined and it will be impossible to prevent, except through litigation, the riparian owners from diverting the released water. This difficulty can be removed by condemnation of rights along the stream. The problem looks too large for human accomplishment in any reasonable time and at any reasonable cost.

To one acquainted with water problems in California, it does not seem reasonable to expect that in the dry part of a dry year a flow of 5,000 or more feet per second would be allowed to pass pumps and ditches, under which crops were suffering, in order that salt water could be pushed back into the ocean.

As to the cost of storage reservoirs to accomplish the release for salt control, there is little definite information which permits a comparison of costs. The following statements are of some interest:

Kennett reservoir is proposed by the State Department of Public Works as a unit in the "Coordinated Plan." (See Bulletin 13, Department of Public Works, 1928.) The recommended reservoir capacity is 2,940,000 acre feet; the estimated cost of dam and rights of way is $55,000,000; of power plant $25,000,000; a total of $80,000,000. With allowances for prior rights, the mean annual irrigation yield of reservoir will be 2,838,000 acre feet. In minimum years the deficiency would be large; 19 per cent in 1920, 42 per cent in 1924. If this reservoir were depended upon for salinity control, the entire available supply would be needed to control salt water at the mouth of the river, leaving no water for the area depending on this reservoir for irrigation. In other words, the very year when the reservoir is most needed it would be of little practical use. Furthermore, Kennett is not practicable unless operated to generate electric power. If the water is held and released for salt water control, the power value is greatly decreased.

Iron Canyon Reservoir is proposed as a secondary unit in the "Coordinated Plan." (See Bulletin 13 of Department of Public Works.) The recommended capacity is 1,121,900 acre feet; the estimated cost of dam and power plant is estimated as $26,000,000; the canal system to utilize this water is estimated at $30,000,000. The reservoir may be utilized in controlling salinity. To quote from the above mentioned report, page 115:

> "Sacrificing the power features at Iron Canyon dam would, with other construction unchanged with the exception of the arrangement of outlets through the dam, supply a reserve storage of 364,600 acre feet of water in Iron Canyon reservoir to overcome, or alleviate, the salt water menace in the delta region should such be desirable. Such use is not advocated, but it is demonstrated that there are possibilities along this line."

Should the irrigation feature likewise be disregarded, Iron Canyon would provide a net annual irrigation draft of 800,000 acre feet or just about enough water to control salt water as low as the mouth of the river—provided the water could be carried past head gates and pumps on its way to tidal waters. Under this condition the power feature would be sacrificed to a larger extent. It is difficult to picture a dry year when water and power are both scarce, in which it would be possible to release a large quantity of water, disregarding its best use for power, and have the riparian and appropriative users of water along the hundred and fifty miles of the Sacramento River permit this flow to pass by uninterrupted to tide water. The plan does not look practical.

Other reservoirs may be used for the same purpose, that of increasing the flow to control salt water. For example, a reservoir on Feather River has been suggested, another on the American at Folsom. Both of these reservoirs will have value for power development and that value will be greatly reduced if a large quantity of water is held for saline control. The most practical suggestion is in connection with a reservoir on Dry Creek, north of the Mokelumne, the water to be diverted from the Mokelumne River. The rights obtained by the East Bay Municipal Utility District for storage in Lancha Plana Reservoir practically eliminate this reservoir from consideration.

In connection with the proposal for storage and release of water, it should be remembered that the State Department of Engineering has made the suggestion as a temporary expedient, with the expectation that permanent relief would be brought about by the construction of the salt water barrier. This state of affairs would leave the delta lands dependent on a temporary right to be replaced by a permanent right which would be arranged for at some later time. With the growing condition of California and the certainty that the temporary supply will be invaded by increased diversions, this is a very precarious water right, not one which will satisfy the delta land owners. Furthermore, the plan does not consider users below the delta, either towns or industries.

New industries will not be attracted by any temporary improvement in water conditions. Some permanent solution must be reached. It is important to California to have the decision made at once so that the great industrial expansion now going on can be located to a maximum extent in this state.

WATER FROM OUTSIDE SOURCES

Water may be brought in from outside sources to supply the towns and industries along the Straits and Suisun Bay. It is not likely that the agricultural lands can be reclaimed by any outside source of water on account of the high cost. But for the uses of towns and factories it is possible to secure outside water.

Under present conditions water cannot be drawn at any point on tide water without either running the risk of getting salt water or of interfering with rights already vested. It may be possible to pump during the fresh water period into reservoirs and to pipe the water thus stored along the waterfront, supplying both domestic and industrial consumers. Reservoirs of good size are available in the Montezuma hills north of Suisun Bay and a few small reservoirs are found on the south side of the bay. No estimate has been made of the cost of this method. Surveys beyond the scope of this report would be required. It is known that the cost would be large, though cheaper than any other known source.

Other possible outside sources are:

Eel River—a supply which has been suggested for both San Francisco and East Bay cities. The distance to Carquinez Strait is 125 miles. Harroun estimates the cost at $22,000,000 to carry 50,000,000 gallons daily to south sides of Carquinez Straits.

Conn Valley—a small tributary to Napa River with probable yield of 10,000,000 gallons daily. Cost not known but the supply would only furnish a part of present needs and would provide nothing for future growth.

Putah Creek—a tributary of Sacramento north of Dixon. Cost not known. About 50 miles north of Suisun Bay. Complicated with riparian claims. All storage at considerable distance in mountains.

Mokelumne or Cosumnes—draining Sierras north of Stockton. Cost unknown. Early rights conflicting. About 75 miles distant.

Pumped water from San Joaquin Valley—It has been suggested that the irrigation districts in the San Joaquin Valley could deliver pumped drainage water into the river to be pumped out above salt water limit and delivered to industries and towns along the bay through pipe lines.

East Bay Municipal Utility District—The main pipe line of this district parallels the bay shore from Antioch to Bay Point. To secure water from it the area must enter the district. The district has voted $64,000,000 to complete a 60 m.g.d. supply. Water will be costly if the entire cost is collected from rates, and there is little incentive for Contra Costa County and towns to enter this organization. The water is too costly for the heavy industries, such as now are located along the waterfront.

All of these sources are so distant and costly that the supplies are more of the nature of domestic supplies than of cheap industrial water supplies such as are required in any large and growing industrial region. None of them solves the salt water problem as affecting construction along the waterfront and none of them can possibly be made available for agricultural industries on the bay lands.

THE BARRIER AS A UNIT IN THE STATE COORDINATED PLAN OF WATER CONSERVATION

A plan for the development and use of all waters of the state upon a coordinated plan has been presented in part to the Legislature by the State Department of Public Works. This plan provides for the storage and utilization of all water required in the Sacramento Valley and the transmission of excess water to the San Joaquin Valley for use on lands for which insufficient water can be supplied from local sources. The salt water barrier is a necessary unit in this plan, for water can not be carried through the delta with tidal flow bringing salt water in and out of the channels twice a day.

GENERAL DEVELOPMENT OF BAY REGION

The entire bay region is interested in the salt water problem in that the prosperity of the region immediately concerned affects the prosperity of the cities. The industrial territory along Carquinez Strait is essential to the well being of the whole state. The industries are fundamental to modern civilization. Oil, gasoline, lubricants, steel, fertilizers, sugar, leather, timber, soda, chlorine, fire-proof roofing, paper board, brick, tile, flour, mill feed, and the remaining varieties of manufactured products are necessities of modern existence. To have them abundant and cheap is greatly to the advantage of modern society.

Many of these factories would be classed as nuisances if located in a large city, on account of the odors. Carquinez Strait and Suisun Bay have regular winds which prevent a serious nuisance in this locality. Other communities are not so fortunately situated.

The ratio of factory employees to population of towns is about 1 to 4. This means that the population of the towns immediately surrounding the industries will grow as the industries thrive. This population in towns makes a market for the products of the cities and the multitude of manufacturing establishments which have located in the cities. The heavy industries in turn furnish raw material for use in the factories in the cities.

As a result of this interlocking of interests, the large cities of the bay region have a direct interest in seeing a salt water barrier established. Behind it, around the fresh water lake thus created, there will grow up a thriving industrial community engaged in the production of essential materials which could not be produced within the cities themselves.

CALIFORNIA NOW IN THE INDUSTRIAL AGE

California is now in an age of industrial growth. Approximately one-third of the people of the state are engaged in manufacturing and mechanical industries as compared with less than 20 per cent engaged in agriculture, forestry and animal husbandry (the next largest class of workers). The present growth of the state is due largely to the activity in industrial matters.

Students of population growth recognize cycles of increase in population. There seems to be a definite limit to the number of people that can be reached in any set of circumstances. The growth of California very well illustrates three cycles of growth. In the early days of the state, mining was the attraction and the whole life of the community centered around the mines. As mining reached its climax in the seventies, agriculture came to the forefront and there was a continuous growth on this account. The agricultural era lasted until about 1915. In the meantime, through the discovery of oil and the unprecedented development of the electrical industry, cheap power was made available and manufacturing began to grow. At present there is very little actual increase in agricultural population but a large increase in industrial activities. So far as it is possible to see in the future, our growth will be industrial. Agriculturists have learned to grow more crops with less man power and there is comparatively little likelihood of any large increase in agricultural population. The problems of the state are nowadays to a large extent those of the people of the towns and cities and industrial areas.

DISTRIBUTION OF BARRIER COST

Several interests should share in the cost of this barrier. As has been shown, conditions now existing have been brought about by developments on the higher parts of the watershed, an area covering 32,000 square miles. The Bay cities will be contributing to the salt water problem by diversions which they propose to make out of the watershed. The agricultural interests through both valleys are using fresh water in such a way as to contribute to the salt water troubles of the delta lands and the industrial territory. The power companies through use of water in the watershed also affect the problem, and in addition these companies are interested in the increase and prosperity of the industrial region. Other public utilities in this region have the same interest in its prosperity.

The problem is so large and its interests so widespread that it may be said to be state-wide in scope.

The federal government through its control of navigation, as well as its general interest in the prosperity of the country, is likewise interested in the problem. The California Debris Commission and the River and Harbor work under the Chief of Engineers of the Army already are engaged in river improvement and in control of reclamation work so far as it affects navigation. It would appear reasonable, therefore, to have participation in this construction work by the federal government.

Local interests which will receive direct and tangible benefits from this barrier, such as the towns, cities and lands which can use water directly from the fresh water lake above the barrier, should contribute to the cost of the structure. The delta lands so far as they divert water from tide water levels should also be included in the area contributing because of benefits.

Railroads and vehicular traffic utilizing the barrier as foundation of a bridge should pay the value of this service. It seems reasonable that railroad and vehicular traffic could reasonably contribute a large sum for the use of the bridge.

It appears from examination of Young's estimates that the sum of $45,000,000 will complete a barrier with a bridge at a point near the upper end of Carquinez Strait. A detailed economic study should be made to determine the proportion of the cost that should be borne by each interest involved.

SUMMARY

1. Carquinez Strait marked approximately the boundary between salt and fresh water under natural conditions.
2. Prior to diversions for irrigation, Suisun Bay was brackish in late summer and salt water may have penetrated as far as Antioch, but only for a few days at a time in years of lowest run-off.
3. If the water now diverted for irrigation and held in storage were released, natural conditions would again be brought about.
4. The dry year of 1918, in which the urge of war had encouraged heavy plantings of rice and other crops in the Sacramento Valley, resulted in penetration of salt water into the Delta for a longer time and to a greater distance up-stream than ever known before.
5. Examination of available information shows that the yearly increased diversion of water which had been going on since irrigation commenced in the valleys of California, had been gradually affecting the movements of salt water. This slow effect was hardly noticed until 1918.
6. Irrigation and storage are not solely responsible for the influx of salt water. The load of hydraulic mining debris deposited in the streams draining the Sierra Nevadas is a minor factor in the problem. As the sediment moves down-stream the tidal prism is changed and the movement of water is affected.
7. Leveeing and reclamation of marsh lands, around the bays and in the delta region, have had a slight effect upon tidal movements. The net effect of leveeing marsh land has been to decrease the tendency of salt water to flow up-stream.
8. Leveeing of basin lands and diversion of floods through by-pass channels has had an important effect in sending floods rapidly to tide water and in reducing the late summer flow of water which under natural conditions was stored and slowly released from basins.
9. Dredging, particularly in lower portions of the rivers and in the navigation channels of San Pablo Bay, has increased the tendency for salt water to flow up-stream. Dredging in Suisun Bay and in the deep water channels to Stockton may have the same tendency. All increases in channel depth and in straightening of approach have a tendency to increase up-stream flow of salt water, though a quantitative estimate of this tendency cannot be made.
10. Irrigation now diverts the entire low flow of all streams entering the San Joaquin Valley. The only flows reaching tide water in late summer and early fall are return waters—seepage from irrigation.
11. Pumping plants on the west side of the San Joaquin Valley, lifting water to the west side slopes, now divert more water during late summer than enters tide-levels from the river. The San Joaquin delta under present conditions is dependent in late summer of dry years on flow from the Sacramento River. Additional pumping plants are being installed and there will be a greater tendency in the future than in the past for salt water to flow up-stream into the delta channels.
12. Irrigation in the Sacramento Valley in late summer diverts practically all the flow of streams entering the valley floor. The flow of the river at Sacramento, the head of tide water, is now largely return seepage or waste from canals. The low flow at Sacramento was 500 second feet in 1920; 2750 in 1921;

3200 in 1922; 3100 in 1923; 705 in 1924; 2760 in 1925; 1330 in 1926; and 3420 in 1927.

13. The area irrigated in the delta of both rivers is now 360,000 acres. The quantity of water used by this land has not been determined with any accuracy. Comparing crops and other conditions affecting use of water, it is probable that the annual consumption approximates 1¾ acre feet per annum. Twenty per cent of the annual amount is used in the summer months of greatest evaporation. At this rate the consumption of water by the delta area is at the rate of 2100 second feet in the summer. This exceeds the flow into tide water by the river in all years of low flow.

14. Records of salt content of the water have been collected by the Division of Water Rights since 1917. The area of delta land surrounded by salt water (100 parts chlorine per 100,000) at high tide is shown in the following table:

Year	Approximate Stream Flow before Diversions in Per Cent of Normal.	Area in Delta Surrounded by Salt Water, Acres.
1924	24	169,000
1926	53	58,000
1925	74	8,500
1927	100	5,000

15. Contrary to popular opinion, the period since 1918 has not been one of stagnation in irrigation development. A number of large storage reservoirs have been built and placed in operation since then. Of approximately 4,000,000 acre feet of storage reservoirs on streams draining through Carquinez Strait, 55 per cent or 2,725,000 acre feet have been built since 1920. Diversions of water, particularly on the lower San Joaquin River, have increased.
The area under irrigation has steadily increased in both valleys. In 1926 it is estimated that 1,250,000 acres were irrigated in the floor of the valley with 3,900,000 acre feet of water by diversions from streams draining toward Carquinez Strait. If mountain valleys and lands irrigated from wells are included, the total area irrigated is probably over 1,750,000 acres.

16. Further extensions of irrigated area are being planned in both valleys. Within the next five years the bay cities will have diverting capacity of about 185 second feet and will control 431,000 acre feet of storage reservoirs. These enterprises will tend to increase the salt water menace. There is reason to expect the same menace of salt water as occurred in 1920, 1924 and 1926 to be present every year.

17. Salt water will penetrate the lower delta region every summer under present conditions. The distance water will flow up-stream will depend less and less upon the flow of streams into the valleys as the increase in use of water continues. About one-half of the delta is likely to be menaced any year. The area may extend beyond this line.

18. There is now no legal control of diversions, other than by the slow and costly process of litigation, except upon a few small tributary streams where the Division of Water Rights has completed adjudications. Litigation between lower users of water in the delta and upper riparian users and appropriators has been in progress for several years. Other litigation may be started. The legal pro-

cesses are so slow, cumbersome and costly that little result is to be expected for many years, if ever.

The outcome of present litigation will be disastrous if the courts uphold the contentions of either of the parties to litigation. If the delta lands have riparian rights to the waters, a large area of land will have to release water, and storage reservoirs constructed by power companies will be decreased in efficiency and value. On the other hand, if the courts decide that riparian rights do not attach to lands on tide water, the delta will be further menaced by salt water and there will be grave danger of permanent injury to a large area of land.

19. The engineering study of a salt water barrier made by Walker Young, of the Bureau of Reclamation, in cooperation with the Department of Public Works of the State of California, concludes that the construction of such a barrier is feasible. Investigations were made at three sites—Point San Pablo, Dillon Point and Army Point. The estimated cost of the barrier with and without bridges is given in the table on Page 60.

20. This barrier will maintain a fresh water reservoir free from tidal fluctuations and currents other than those caused by the flow of river water toward the sea. The level of water up-stream of barrier will be maintained at the highest practical level. Young estimates this level at elevation 2.5, U. S. G. S., or 6.0 on tide gage. It is probable that this height of water will be controlled by conditions of levees in the peat areas. As these levees become more stable the level can be increased. Flood levels will not be increased above those of floods in the past, in fact flood conditions will be improved in all but the most severe and protracted floods.

21. The salt water barrier, if built, will affect agriculture and the industries and activities along the bay and lower river as shown in the following statement:

A. AGRICULTURE

(a) A salt water barrier at Point San Pablo will make fresh water available for the irrigation of 51,000 acres of marsh and 48,000 acres of high land around San Pablo Bay. There is no known source of water for this area of land at present. If such lands are increased $50 an acre above cost of irrigation works, the total increase in value will be $4,950,000.

(b) A salt water barrier in Carquinez Strait or at Army Point will make fresh water available for 163,000 acres (marsh 70,000 acres; high lands 93,000 acres) around Suisun Bay. There is no other known source of water for this area. At $50.00 an acre, the increased value above cost of irrigation works will be $8,150,000.

(c) Either location of barrier will solve the irrigation problem for the lands now irrigated from tide waters in the delta and adjoining it. The area now watered is about 360,000 acres. The total area of irrigable lands is estimated as 458,000 acres. The area menaced by salt water is 169,000 acres. The value of this land is $35,000,000. Improvements at 20 per cent of land value add another $7,000,000.

There will be some increment in value to all the delta area from the security which the salt water barrier will bring about.

(d) The salt water barrier will benefit the areas up-stream from tidal lands by removal of litigation which is now a source of expense and annoyance and which is an obstacle to future projects.

SALT WATER BARRIER

Comparison of Estimated Costs for Alternate Design at Four Sites.

DISTINGUISHING FEATURES OF ASSUMPTIONS OF DESIGN

No.	Estimated Cost	Highway and Railway Bridge			Locks		Flood Control Gates			Pier Width
		Minimum Clearance at Locks	Decks	Piers or Towers	No.	Location	No.	Size	Location	
				ARMY POINT-SUISUN POINT AND ARMY POINT-MARTINEZ						
1	$46,300,000		No Bridge		3	In Suisun Point	14 2	70x80 50x60	Partially in Suisun Pt.	20 Ft.
2	49,800,000	50 Ft.	Single	Concrete	3	In Suisun Point	do	do	Partially in Suisun Pt.	15-20
3	54,100,000	50 Ft.	Single	Concrete	3	In Suisun Point	30	50x60	Partially in Suisun Pt.	15 Ft.
4	55,900,000	50 Ft.	Single	Concrete	3	Offshore from Suisun Pt.	15	70x80	Partially in Suisun Pt.	20 Ft.
5	58,500,000	50 Ft.	Single	Concrete	3	Offshore from Suisun Pt.	30	50x60	Partially in Suisun Pt.	15 Ft.
6	77,300,000	50 Ft.	Single	Concrete	3	Offshore from Martinez	15	70x80	Offshore from Martinez	20 Ft.
						BENICIA-PORT COSTA				
7	40,200,000		No Bridge		4	In Benicia	30	50x60	Offshore from Benicia	15 Ft.
8	46,200,000	50 Ft.	Single	Concrete	4	In Benicia	30	50x60	Offshore from Benicia	15 Ft.
						DILLON POINT-ECKLEY				
9	38,900,000		No Bridge		4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
10	44,700,000	50 Ft.	Double	Concrete	4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
11	44,900,000	50 Ft.	Double	Steel	4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
12	47,600,000	135 Ft.	Double	Steel	4	In Dillon Point	15	70x80	Offshore from Eckley	50 Ft.
13	50,400,000	50 Ft.	Double	Concrete	4	In Dillon Point	21	70x80	Across Carquinez Sts.	50 Ft.
14	50,600,000	50 Ft.	Double	Steel	4	In Dillon Point	21	70x80	Across Carquinez Sts.	50 Ft.
15	53,300,000	135 Ft.	Double	Steel	4	In Dillon Point	21	70x80	Across Carquinez Sts.	50 Ft.
16	97,100,000	50 Ft.	Single	Concrete	4	In Dillon Point	15	70x80	In Dillon Point	20 Ft.
						POINT SAN PEDRO-POINT SAN PABLO				
17	66,000,000		No Bridge		5	In Point San Pablo	15	70x82	Offshore Pt. San Pablo	20 Ft.
18	75,200,000	50 Ft.	Single	Concrete	5	In Point San Pablo	15	70x82	Offshore Pt. San Pablo	20 Ft.
19	82,100,000	50 Ft.	Single	Concrete	5	In Point San Pablo	15	70x82	In Point San Pablo	20 Ft.

One estimate only is given for the Army Point-Martinez Location—Estimate No. 6.

This site was not drilled—Estimates based largely on assumed foundation conditions except for S. P. Co. test pile data.

NOTE—At all sites except Dillon Point-Eckley, conditions are such that flood gates, locks, piers, etc., would be constructed in the dry behind coffer dams. A limiting depth of 90 feet below mean sea level to rock surface is assumed for this method of construction. The depths at Dillon Point-Eckley exceed this, and Estimates 9 to 15, inclusive, are based upon the placing of concrete under water by the tremie method using caisson gates for the final work on the Stoney Roller Gates. Estimate 16 uses construction methods comparable to those at the other sites as the flood gates are placed in Dillon Point.

(e) The salt water barrier is a step in the direction of carrying out the state's plan of supplying water to the Southern San Joaquin Valley—a step in the coordinated plan of water development. It is the first portion of the project which should be built.

B. INDUSTRIES

Industries occupy a large area of land along the waterfront of San Francisco and San Pablo bays, Suisun Bay and Carquinez Strait. Between Oleum and Antioch there are seventeen large industrial plants and a number of smaller ones. On the north side of the straits there are two large industries besides the Mare Island Navy Yard and Benicia Arsenal.

These industries are of the "heavy" type, fundamental industries, which produce essential products necessary both in war and peace. Steel and iron, petroleum products, chemicals, fertilizers, powder and fuse works, leather, brick and tile, flour and feed, roofing lumber and wood products, fish, canned goods and sugar are produced in large quantities. The products of these works have an annual value of $250,000,000. Freight in and out of the district approximates 14,000,000 tons a year. Expenditures for electric power average $800,000 a year. The average number of employees is 8500, having an annual payroll of about $15,000,000. The portion of the population of towns and suburban territory dependent on these industries includes 30,000 inhabitants.

The industries are large users of water. At present 10 million gallons a day are used, not including the Navy Yard or Arsenal, and the annual increase in use by the establishments is one million gallons a day.

Immediately adjoining the industrial area above described are other large establishments which could receive benefit from the fresh water reservoir created above the barrier. If the zone along the waterfront to Richmond were included, the annual value of products for the whole territory would be $515,000,000; the number of employees 17,000; the annual payroll $29,000,000. A part of this area is within the East Bay Municipal District.

Since the salt water menace became widely advertised through the Antioch litigation, only one new industry of large size has been established in this territory. The factories already established have continued to grow but the uncertainty about fresh water has discouraged new industries seeking location. Fresh water in large quantities at low prices is essential to the prosperity of such establishments. Water from any existing utility or municipal district is too high in price for these "heavy" industrial plants.

Ordinarily such works locate where water can be had for the cost of pumping, and such manufacturing establishments will not go to any place where practically free water is not available. There is no other location in California suitable for heavy industries where this condition can be created.

The establishment of new basic industries will be attracted to abundant cheap water. If California does not provide the proper location, Seattle or Portland or some other northern locality will offer greater inducements and many industries will establish Pacific Coast branches in these northern cities. There are in these other states large areas of land where pure fresh water is abundant and may be had for the cost of pumping from permanent running streams. Further than this, rates for water in the cities are cheaper than in California. Below are given the costs of 500,000 gallons of water in the principal Pacific Coast cities:

Cost of 500,000 Gallons of Water Per Month

San Francisco	$157.56
Oakland	161.71
Los Angeles	72.16
Stockton	54.50
Portland	44.11
Seattle	32.94

One of the greatest needs of the state today is a fresh water reservoir around which factories could be located with assurance of a permanent supply of water. Probably no single accomplishment in the construction program now under discussion would do more toward progress. More factories mean greater population and more local markets for agricultural produce, and the general level of prosperity of the state will be raised.

Salt water is detrimental to the piping and more costly to handle in factories of this sort. The increased annual cost to the users of saline water is estimated to be $300,000 a year through deterioration of equipment and piping in the industries now established. This sum capitalized at 6% means the equivalent of an investment of $5,000,000.

Some of the industries, notably the sugar refinery at Crockett and the chemical works at Pittsburg and Nichol, require water free from saline matter. The presence of salt water in the river for long periods of each year has been the cause of much expense and annoyance in these establishments, and brings seriously to consideration the ability of these factories to continue to exist under the trying conditions.

The salt water barrier will remove the cause of additional expense to the plants now located here, will encourage their more rapid growth, and will offer a great incentive to new establishments to locate here. Large industries require, in addition to large quantities of pure water, cheap power, efficient transportation facilities, preferably both by rail and water, and a good climate attractive to labor. The lower river and upper bay regions lack only water. The salt water barrier will supply this single deficiency. If the barrier is not built, California, without doubt, will lose many important factories.

C. DOMESTIC WATER SUPPLY

The domestic water supply of towns along the straits in Suisun Bay is high in price and limited in quantity. Vallejo, the only exception to this statement, recently has constructed Gordon Valley Reservoir on Suisun Creek, and has a permit to store 10,000 acre feet and to divert 5,000 acre feet annually. Other towns have no large amount of water for future growth. In fact lack of available water has been a deterrent to the location of industries and the resultant increase in population.

A salt water barrier will solve the water difficulties. If the barrier is located at San Pablo Point, the entire area can be supplied with fresh water; if the barrier is located at Army Point or in Carquinez Strait, all towns on Suisun Bay and in the lower river will be on fresh water; towns below the barrier, such as Crockett, can be readily supplied with short pipe lines heading above the barrier.

Either barrier will be of benefit to the city of Sacramento in preventing the up-flow of tide and reducing the menace of sewage water being carried toward the water intake.

D. TRAFFIC ACROSS STRAIT

Routes of travel between northern and southern parts of the state naturally pass through Carquinez Strait. The Southern Pacific Company maintains ferries for trains between Benicia and Port Costa and for passengers between Vallejo Junction and Vallejo. The Sacramento-San Francisco Railroad maintains a train ferry from Mallard to Chipps Island. A bridge for vehicular traffic now crosses the strait just below Crockett. A ferry for automobiles and passengers is maintained between Martinez and Benicia.

At Richmond an automobile ferry is in operation a short distance below the site of the proposed salt water barrier at Point San Pablo.

A barrier at San Pablo can be made to serve as a bridge. There are now two applications for bridge permits near this place. The estimated cost of these bridges is from $10,000,000 to $20,000,000. The difference between the cost of a barrier with and without bridge is estimated by Young to be $9,000,000.

At Army Point a bridge 50 feet above water increases the cost $3,500,000; at Benicia a bridge 50 feet above water level increases the cost $6,000,000; at Dillon Point a bridge with a clearance of 50 feet increases the cost $3,800,000; a bridge with clearance of 135 feet increases the cost $8,700,000. Approximate figures indicate that a railroad bridge near the location of the present Southern Pacific ferry between Benicia and Port Costa will cost in excess of $10,000,000. Upon this estimate railroad transportation could bear a part of the cost of barrier. Vehicular traffic is growing so rapidly that there will be need for a second bridge across the straits within a few years.

E. POWER COMPANIES

The power companies are interested in the salt water problem because it has decreased their market for power by discouraging new plants from locating here and by reducing the growth of those already established.

The litigation over water rights may seriously affect their plants supplied from storage in the mountains.

F. FISHING INDUSTRY

Fishing in the bay and rivers is important. Salmon, shad and striped bass are important commercial fish. Smelt and smaller fish are important in furnishing food for commercial varieties. Sturgeon are nearly extinct but it is the endeavor of the Fish and Game Commission to prevent complete extinction and to encourage increases in this species.

The salt water barrier will be an obstacle to migrating fish during low water season. Young's plans provide for fishways and it is his belief that fish will use the locks and that on the whole the barrier will not obstruct the migration. Objection to any forms of barrier will be raised by the fishing industry. Wherever the structure is built there will naturally be some obstruction to free migration of the fish. It is probable, however, that the structure can be so designed and operated as to do only a small amount of damage.

G. NAVIGATION

Any barrier is an obstacle to free movement of vessels, and it is to be expected that owners of vessels will object to the project. This objection arises from the delays caused by using locks and the danger of handling vessels in such restricted quarters, particularly in foggy periods.

As to delays, it may be said that ordinarily the time lost in transit through locks will be regained by the freedom from adverse currents above the locks. While this will depend upon the place to which the vessel is bound, it is believed that for the great bulk of traffic the delay is likely to be small.

The danger to vessels maneuvering in approach to locks is of course real, but with the safeguards now provided for vessels the risk is small and there are compensating advantages. The ability to dock without tidal currents, as would be true above the barrier, is both a saving in time and reduction of risk. The cleansing action of fresh water upon the bottoms of ocean-going vessels is valuable.

The fear that the barrier will cause silting in channels or will create changes in the Golden Gate bar does not seem to be well founded. Sediment moves almost entirely at flood times when the barrier will be open and the current constantly down-stream. The movement of sediment will probably be facilitated rather than retarded.

Owners of shipping facilities are of course interested in the growth and prosperity of the communities served. The industrial area which will grow up around the fresh water reservoir above the barrier will produce freight for vessels at a greatly increased rate. The depth of water through Suisun Bay and to Stockton will be increased to 26 feet under the plan already adopted by Congress. This depth of channel will be ample for from 73 to 88 per cent of the vessels normally entering the Golden Gate during a year.

In considering the location of the barrier, the extent of shipping is important. The farther downstream the greater the traffic through locks, the greater the quantity of water required for lock operation, and the greater will be the objection by the shipping interests. In this regard the upper location of the barrier will meet with the least objection.

The Navy Yard is above San Pablo site and naval officers will probably be impressed with the difficulties presented by the barrier in time of war. Here we have another and important reason for the selection of the upper site.

H. STRUCTURE BUILT IN WATER

Teredos and other wood-destroying animals have caused damage to structures in San Francisco Bay waters in excess of $25,000,000 since 1914, according to estimates made by the San Francisco Bay Marine Piling Committee. In the upper bay region, teredos have gone as far as Antioch. All structures built in water which may become brackish must be constructed of treated piles or of concrete. Brackish water carried up by tides will continue to cause greater expense in all structures built in water and greater maintenance costs. It is difficult to measure this damage in dollars, but it is a very considerable sum annually.

A salt water barrier will reduce the maintenance cost of structures and will make it practical to build structures as economically as was done prior to the invasion of salt water.

I. THE BARRIER AS A UNIT IN THE STATE'S COORDINATED PLAN OF WATER CONSERVATION

A plan for the development and use of all waters of the state upon a coordinated plan has been presented in part to the legislature by the State Department of Public Works. This plan provides for the storage and utilization of all water required in the Sacramento Valley and the transmission of excess water to the San Joaquin Valley for use on lands for which insufficient water can be supplied from local sources. The salt water barrier is a necessary unit in this plan, for fresh water cannot be carried through the delta with tidal flow bringing salt water in and out of the channels twice a day.

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The entire bay region is interested in the salt water problem in that the prosperity of the region immediately concerned affects the prosperity of the cities. The industrial territory along Carquinez Strait is essential to the well-being of the whole state. The industries are fundamental to modern civilization. Oil, gasoline, lubricants, steel, fertilizers, sugar, leather, timber, soda, chlorine, fire-proof roofing, paper board, brick, tile, flour, mill feed, and the remaining varieties of manufactured products are necessities of modern existence. To have them abundant and cheap is greatly to the advantage of modern society.

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The ratio of factory employees to population of towns is about 1 to 4. This means that the population of the towns immediately surrounding the industries will grow as the industries thrive. This population in towns makes a market for the products of the cities and the multitude of manufacturing establishments which have located in the cities. The heavy industries in turn furnish raw material for use in the factories in the cities.

As a result of this interlocking of interests, the large cities of the bay region have a direct interest in seeing a salt water barrier established. Behind it, around the fresh water lake thus created, there will grow up a thriving industrial community engaged in the production of essential materials which could not be produced within the cities themselves.

CALIFORNIA NOW IN THE INDUSTRIAL AGE

22. California is now in an age of industrial growth. Approximately one-third of the people of the state are engaged in manufacturing and mechanical industries as compared with less than 20 per cent engaged in agriculture, forestry and animal husbandry (the next largest class of workers). The present growth of the state is due largely to the activity in industrial matters.

Students of population growth recognize cycles of increase in population. There seems to be a definite limit to the number of people that can be reached in any set of circumstances. The growth of California very well illustrates three cycles of growth. In the early days of the state, mining was the attraction and the whole life of the community centered around the mines. As mining reached its climax in the 70's, agriculture came to the forefront and there was a continuous growth on this account. The agricultural era lasted until about 1912. In the meantime, through the discovery of oil and the unprecedented development of the electrical industry, cheap power was made available and manufacturing began to grow. At present there is very little actual increase in agricultural population but a large increase in industrial activities. So far as it is possible to see in the future, our growth will be industrial. Agriculturists have learned to grow more crops with less man power and there is comparatively little likelihood of any large increase in agricultural population.

The problems of the state are nowadays to a large extent those of the people of the towns and cities and industrial centers.

SOLUTION OF THE SALT WATER PROBLEM

23. The salt water problem may be partially solved in several ways but completely only in one way. Conditions may be ameliorated by storage and release of water from reservoirs to push back the salt water or water supply from outside sources may be brought in to supply fresh water through conduits or pipes.

The only satisfactory solution of the problem is the salt water barrier.

These methods are briefly discussed below:

STORAGE AND RELEASE TO PUSH BACK SALT WATER

24. This method of solving the salt water problem has been suggested in several recent publications of the Department of Public Works. Examination in detail of the proposals shows that "salt water control" means the supplying of water of less than 100 parts chlorine per 100,000 to the delta lands.

Emmaton on the Sacramento River and Jersey Island on the San Joaquin are the limits of control and no suggestion has been made that it is practical to release water to supply Antioch or any of the lower industrial area. This, in fact, leaves out of consideration the area now most seriously damaged.

Studies by the Division of Water Rights based on records including the year 1925 show that to control salinity below 100 parts chlorine per 100,000, the combined flow of Sacramento River at Sacramento and the San Joaquin at Vernalis (both points about head of tide water in late summer) must exceed the following figures:

For Control at	Cubic Feet Per Second
Emmaton and Jersey Island	3500
Antioch	5000
Collinsville	5500
O. & A. Ferry	6000

These quantities will depend to some extent upon the months preceding the period when control is desired, and will, of course, vary with the diversions below the points of measurements. Furthermore, storage of water above tide level will affect the matter by limiting the distance salt water is forced downstream by spring floods.

To effectively supply these quantities of water will require very large storage capacity in dry years.

In 1924 storage in excess of a million acre feet would have been required to control salinity at the O. & A. Ferry and 200,000 acre feet at Emmaton and Jersey.

Storage in large amount would be needed about half the years at Emmaton and Jersey, and every year for control at the O. & A. Ferry.

The above is under the assumption that storage and diversions in these two valleys does not increase. As shown earlier, this condition has already been violated, for there has never been such increased activity in building storage reservoirs as in the period since 1924. Many reservoirs are planned for construction in the near future. Furthermore, diversions increase every year.

Estimates of the quantities required for storage control must therefore be continuously revised upwards.

Release of stored water, to control salinity, will occur in dry parts of the year and to greatest extent in dry years. To effectively control the right of storage and release, all riparian owners below the reservoir must agree to the arrangement. As the law now stands, the use of such a reservoir may be enjoined and it will be impossible to prevent—except through litigation—the riparian owners from diverting the released water. This difficulty can be removed by condemnation of rights along the stream. The problem looks too large for human accomplishment in any reasonable time and at any reasonable cost.

To one acquainted with water problems in California, it does not seem reasonable to expect that in the dry part of a dry year a flow of 5,000 or more feet per second would be allowed to pass pumps and ditches, under which crops were suffering, in order that salt water could be pushed back into the ocean. As to the cost of storage reservoirs to accomplish the release for salt control, there is little definite information which permits a comparison of costs. The following statements are of interest:

Kennett Reservoir is proposed by the State Department of Public Works as a unit in the "Coordinated Plan." (See Bulletin 13 of the Department of Public Works, 1928.) The recommended reservoir capacity is 2,940,000 acre feet; the estimated cost of dam and rights-of-way is $55,000,000; of power plant $25,000,000; a total of $80,000,000. With allowances for prior rights, the mean annual irrigation yield of reservoir will be 2,838,000 acre feet. In minimum years the deficiency would be large; 19 per cent in 1920; 42 per cent in 1924. If this reservoir were depended upon for salinity control, the entire available supply would be needed to control salt water at the mouth of the river, leaving no water for the area depending on this reservoir for irrigation. In other words, the very year when the reservoir is most needed it would be of little practical use. Furthermore, Kennett is not practicable unless operated to generate electric power. If the water is held and released for salt water control, the power value is greatly decreased.

Iron Canyon Reservoir is proposed as a secondary unit in the "Coordinated Plan." (See Bul. 13, Dept. of Public Works.) The recommended capacity is 1,121,900 acre feet; the cost of dam and power plant is estimated as $26,000,000; the canal system to utilize this water is estimated at $30,-000. The reservoir may be utilized in controlling salinity. To quote from the above mentioned report, page 115:

"Sacrificing the power feature at Iron Canyon dam would, with other construction unchanged with the exception of the arrangement of outlets through the dam, supply a reserve storage of 364,600 acre feet of water in Iron Canyon reservoir to overcome, or alleviate, the salt water menace in the delta region should such be desirable. Such use is not advocated, but it is demonstrated that there are possibilities along this line."

Should the irrigation feature likewise be disregarded, Iron Canyon would provide a net annual irrigation draft of 800,000 acre feet or just about enough water to control salt water as low as the mouth of the river—provided the water could be carried past head gates and pumps on its way to tidal waters. Under this condition the power feature would be sacrificed to a larger extent. It is difficult to picture a dry year when water and power are both scarce, in which it would be possible to release a large quantity of water, disregarding its best use for power, and have the riparian and appropriative users of water along the hundred and fifty miles of the Sacramento River permit this flow to pass by uninterrupted to tide water. The plan does not look practical.

Other reservoirs may be used for the same purpose, that of increasing the flow to control salt water. For example, a reservoir on Feather River has been suggested, and another on the American at Folsom. Both of these reservoirs will have value for power development and that value will be greatly reduced if a large quantity of water is held for saline control. The most practical suggestion is in connection with a reservoir on Dry Creek, north of the Mokelumne, the water to be diverted from the Mokelumne River. The rights obtained by the East Bay Municipal Utility District for storage in Lanch Plana Reservoir practically eliminate this reservoir from consideration. In connection with the proposal for storage and release of water, it should be remembered that the State Department of Engineering has made the suggestion as a temporary expedient, with the expectation that permanent relief would be brought about by the construction of the salt water barrier. This state of affairs would leave the delta lands dependent on a temporary right to be replaced by a permanent right which would be arranged for at some later time. With the growing condition of California and the certainty that the temporary supply will be invaded by increased diversions, this is a very precarious water right, not one which will satisfy the delta land owners. Furthermore, the plan does not consider users below the delta, either towns or industries.

New industries will not be attracted by any temporary improvement in water conditions. Some permanent solution must be reached. It is important to California to have the decision made at once so that the great industrial expansion now going on can be located to a maximum extent in this state.

WATER FROM OUTSIDE SOURCES

25. Under present conditions the towns and industrial area cannot look to any place within tide water level for a source of water. Above tide levels the following are the principal supplies which may be considered:

Eel River,
Conn Valley,
Putah Creek,
Mokelumne or Cosumnes,
Pumped water from irrigation districts, San Joaquin Valley,
East Bay Municipal Utility District.

All of these sources may be considered, but as all are distant, with long pipe lines and other costly works, they will be able to supply water only at relatively high cost, prohibitory to the types of factories now located in Contra Costa and Solano Counties. Piping water across these straits will be a very costly and difficult affair. The barrier removes the necessity of any pipe line crossing.

LOCATION OF BARRIER

26. For the purpose of providing fresh water to cities, industries and agriculture on adjoining land, the lowest location of the barrier accomplishes the most. However, water supply, cost and convenience to other interests must be considered before the location can be selected. The following may be said on these points:

Water Supply. The attached tables give the requirements for fresh water above the barrier upon the assumption that development is complete. These figures, in part, are taken from the Young report—in part are the results of studies made for this investigation.

Requirements for the full year are:

Army Point	1,160,000 acre feet
Point San Pablo	2,024,000 " "
Difference	864,000 " "

For the irrigation period May to September, inclusive, the requirements are:

Army Point	638,000 acre feet
Point San Pablo	1,236,000 " "

Additional storage on the headwaters will be required to supply the barrier at San Pablo.

Cost. Young's estimate of cost of barrier with bridge of clearance of 50 feet is as follows:

Point San Pablo	$75,200,000
Army Point	49,800,000
Difference	$25,400,000

Convenience of Other Interests. San Pablo site is below the Mare Island Navy Yard, a great obstacle. Navy men will be against the project. Shipping interests will be more inconvenienced with the lower site occupied. At present about two-thirds of the vessels that pass Point San Pablo continue upstream above Army Point. The San Pablo site will be a convenience to vehicular traffic. The Army Point site will be convenient for both vehicular and railroad traffic, though at present vehicular traffic is cared for by the Carquinez Bridge.

FINAL CONCLUSION

27. If the salt water barrier is built at Army Point to carry vehicles and railroads, and the proper part of the cost paid by these interests, the salt water problem can be solved permanently and cheaper than by any other solution that has been suggested.

The cost of a bridge for rail and automobile traffic at Army Point cannot be determined without more work than is possible in an investigation such as this. It can be safely said, however, that the cost will exceed $10,000,000. Automobile traffic over the Carquinez Bridge (which has been in use less than a year) is at the rate of approximately 1,100,000 automobiles a year and is growing rapidly. There will be economic justification for an auto bridge at Benicia before it can be built. Automobile traffic will justify an expenditure of over $10,000,000. The two combined will be over $20,000,000. If this figure is taken as the value to transportation, there will be left, approximately, an equal sum to be paid by other benefits.

Iron Canyon Reservoir, the only definite storage reservoir suggested for temporary control, will cost $26,000,000. The salt water barrier would permanently solve the difficulties for a smaller sum.

[TABLE 1]

AVERAGE MILES TRAVELED BY WATER BARGE
CALIFORNIA-HAWAIIAN SUGAR COMPANY

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1908	19.8	11.6	12.5	14.0	12.9	16.7	26.3	26.8	33.2	27.1	24.8	25.7
1909	6.9	0	4.5	7.7	5.0	4.7	10.5	19.4	23.2	24.2	21.0	11.7
1910	9.6	10.0	3.8	3.0	6.4	10.8	20.4	26.7	27.6	25.4	24.6	19.7
1911	11.6	2.3	16.2	1.0	2.1	0.7	5.7	16.4	23.2	24.5	24.7	25.5
1912	22.0	16.1	14.5	12.7	8.8	7.1	17.6	24.7	24.4	24.2	19.0	18.5
1913	16.4	13.6	13.2	9.9	6.9	10.3	21.0	25.7	26.6	27.8	26.1	20.4
1914	2.1	1.2	1.6	2.5	2.2	3.4	10.3	20.0	24.4	24.5	23.9	23.7
1915	16.4	2.3	3.1	4.3	2.6	3.7	12.6	20.8	24.4	24.2	23.0	17.5
1916	4.9	0.5	1.0	2.3	6.4	5.8	13.2	22.6	25.0	21.7	21.2	15.4
1917	16.0	13.1	6.5	6.3	3.5	4.8	15.5	24.9	26.2	26.0	25.1	24.4
1918	24.3	15.1	9.6	6.2	9.2	15.0	27.0	38.5	37.2	23.0	23.1	21.0
1919	20.4	9.4	7.7	5.7	4.3	14.1	35.3	37.7	37.7	26.8	25.7	25.5
1920	23.8	24.0	17.2	12.0	12.9	17.4	26.0					

[TABLE 3]

COMMERCIAL FISHING—SAN PABLO AND SUISUN BAYS AND SACRAMENTO AND SAN JOAQUIN RIVERS

(Varieties)

Year	Salmon Native	Shad Planted	Striped Bass Planted	Total Pounds
1919	4,529,048	1,573,713	759,733	6,862,494
1920	3,860,312	1,409,322	668,290	5,937,924
1921	2,511,127	797,128	599,698	3,907,953
1922	1,765,066	1,109,445	682,717	3,557,228
1923	2,243,945	1,285,334	906,869	4,436,148
1924	2,640,110	1,538,735	658,244	4,837,089
1925	2,778,846	2,439,441	836,301	6,054,588
1926	1,261,776	902,202	749,573	2,913,551
1927	920,471	4,103,012	644,789	5,668,272
Total, 9 Years	22,510,701	15,158,332	6,506,214	44,175,247
Mean	2,501,189	1,684,259	722,913	4,908,361

The run of fish will vary from year to year in accordance with weather, feed and unknown factors.

A low or high run for one year may not mean absolute evidence of either increase or decrease in the species.

For example, the extremely low run of salmon in 1927 does not necessarily mean still lower run in 1928, and similarly with shad in reverse tendency.

However, there seems to be a general decrease in salmon, probably an increase in shad, and a static condition in striped bass.

[TABLE 2]

COMBINED FLOW OF SACRAMENTO AND SAN JOAQUIN TRIBUTARIES

(Flow in Second Feet)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1916	66,670	92,200	99,830	88,621	73,060	55,619	23,990	11,112	9,300	12,261	11,522	19,986
1917	16,712	56,000	34,521	71,153	69,307	63,407	20,082	9,787	8,309	7,875	8,639	11,071
1918	9,180	21,849	50,360	51,091	39,145	32,183	9,563	6,885	8,621	13,041	11,956	12,118
1919	19,653	58,664	44,948	63,700	65,666	18,261	8,975	7,275	7,049	7,733	7,172	11,460
1920	9,075	9,550	26,759	41,822	49,582	27,404	9,931	6,722	6,059	8,557	39,737	48,539
1921	73,000	58,400	69,470	55,291	65,385	50,246	15,606	8,297	7,435	7,589	8,389	19,407
1922	17,560	50,030	41,389	61,190	109,494	82,327	20,879	9,022	7,329	8,334	11,828	35,715
1923	29,742	22,089	23,785	55,290	54,199	31,844	17,138	9,798	8,809	10,004	7,810	7,919
1924	8,617	19,248	10,222	15,623	14,438	7,007	5,981	5,601	5,171	7,056	13,214	15,029
1925	15,018	89,005	34,394	63,127	59,990	32,824	13,486	9,030	8,535	8,626	9,361	11,720
1926	13,056	57,377	26,323	60,494	30,503	13,603	9,732	8,522	7,364	7,730	32,243	31,338
1927	35,293	109,044	54,556	75,100	59,973	45,353	16,984	11,349	10,652			

No allowance for power storage or regulation.

Combination of

Sacramento at Red Bluff,
Feather at Oroville,
Yuba at Smartsville,
Bear at Van Trent,
American at Fair Oaks,

and

Mokelumne at Clements,
Stanislaus at Knights Ferry,
Tuolumne at La Grange,
Merced at Exchequer,
San Joaquin at Friant.

[TABLE 4]

POPULATION OF BAY COUNTIES— U. S. CENSUS

	1920	1910	1900	1890	1880	1870	1860	1850
State	3,426,861	2,377,459	1,485,053	1,213,398	864,694	560,247	379,994	92,597
Alameda	344,171	246,131	130,197	93,864	62,976	24,237	8,927	
Contra Costa	53,889	31,674	18,046	13,515	12,525	8,461	5,328	
Marin	27,342	25,114	15,702	13,072	11,324	6,903	3,334	323
Napa	20,678	19,800	16,451	16,411	13,235	7,163	5,521	405
Sacramento	91,029	67,806	45,915	40,339	34,390	26,830	24,142	9,087
San Francisco	506,676	416,912	342,782	298,997	233,959	149,473	56,802	
San Joaquin	79,905	50,731	35,452	28,629	24,349	21,050	9,435	3,647
San Mateo	36,781	26,585	12,094	10,087	8,669	6,635	3,214	
Solano	40,602	27,559	24,143	20,946	18,475	16,871	7,169	

[TABLE 5]

SCHOOL ENROLLMENT

BAY SHORE DISTRICTS—CONTRA COSTA COUNTY

Elementary Schools:	1915	1921	1927
Oakley	85	118	158
Antioch	333	454	731
Pittsburg	668	1122	1485
Bay Point	85	-------	162
Martinez	403	792	1068
Port Costa	122	108	75
Carquinez (Crockett)	447	572	617
Selby	72	99	128
Rodeo	108	132	198
Pinole Hercules	227	258	217
San Pablo	182	227	282
Richmond	2288	3380	3997
Total Elementary	5020	7262	9118
High Schools:			
Antioch	105 (Antioch and Pittsburg)	142	149
Pittsburg			183
Alhambra, Martinez	77	121	294
John Swett, Crockett	86	119	206
Richmond	242	655	754
Total High School	510	1037	1586
Total both	5530	8299	10,704

[TABLE 6]

WATER-BORNE TRAFFIC

U. S. ENGINEERING DEPARTMENT DATA

(Total Movement, Tonnage and Values in Thousands of Tons and Thousands of Dollars)

	Suisun Bay		Carquinez Strait		San Pablo Bay		Grand Total	
Year	Tons	Value	Tons	Value	Tons	Value	Tons	Value
1917	Do Data		Incl. in San Pablo		11,946	$212,592		
1918	No Data		Incl. in San Pablo		4,330	152,206		
1919	305	$ 7,034	Incl. in San Pablo		4,634	184,476	4,939	191,510
1920	433	13,877	2,079	$97,991	1,696	54,620	4,208	166,488
1921	562	19,670	1,720		2,019	96,177	4,301	
1922	1,329	32,006	No Data		2,652	118,234		
1923	2,659	43,764	No Data		2,466	109,022		
1924	2,341	51,066	No Data		4,200	156,999		
1925	4,204	88,670	7,673	183,000	4,754	234,409	16,631	506,079
1926	4,205	90,687	7,844	135,522	4,667	260,920	16,716	487,129

Totals are only shown where data are complete for all divisions.

In addition to above, in 1926, there was a total of 1,752,000 tons valued at $124,-077,616 to or from the Sacramento and San Joaquin Rivers, most of which passed through Carquinez Strait. However, all of this having origin and destination in the above Bay division, it appears there also.

Railroad ferry freight traffic across Carquinez Strait was, in 1925, 2,706,000 tons; in 1926, 2,650,000 tons.

[TABLE 7]

OCEAN-GOING WATER-BORNE TRAFFIC
U. S. ENGINEERING DEPARTMENT DATA

(Tonnage in Thousands of Tons and Values in Thousands of Dollars.)

Year	Suisun Bay Tons	Suisun Bay Value	Carquinez Strait Tons	Carquinez Strait Value	San Pablo Bay Tons	San Pablo Bay Value	Grand Total Tons	Grand Total Value
1925	2659	$43,823	5188	$147,485	4011	$66,999	11,858	$258,307
1926	2495	41,173	4264	107,228	3866	58,942	10,625	207,343

Data do not permit a separation of bay business from ocean-going business previous to 1925, and Carquinez Straits' data are entirely lacking for thee years.

The magnitude of the Petroleum Products traffic and the proportion of the total it occupies are obvious when the following tables are compared with the above.

Year	Suisun Bay Tons	Suisun Bay Value	Carquinez Strait Tons	Carquinez Strait Value	San Pablo Bay Tons	San Pablo Bay Value	Grand Total Tons	Grand Total Value
1925	2464	$34,391	4415	$ 49,562	3837	$45,714	10,716	$129,667
1926	2168	33,663	3409	40,454	3708	43,837	9,285	117,954
OUTGOING BAY AND OCEAN WATER-BORNE PETROLEUM PRODUCTS								
1925	547	$20,811	2949	$ 38,217	1019	$19,783	4,515	$ 78,811
1926	615	29,989	2746	35,197	940	23,837	4,301	89,023

Does not include Standard Oil Co. Richmond plants.

[TABLE 8]

SACRAMENTO AND SAN JOAQUIN RIVER TRAFFIC
U. S. ENGINEERING DEPARTMENT DATA

(Tonnage and Values)

Year	Sacramento River Tons	Sacramento River Value	San Joaquin River Tons	San Joaquin River Value
1910	496,147	$ 29,522,151	631,681	$ 32,878,108
1911	505,285	32,139,048	600,128	35,768,215
1912	477,292	27,755,325	632,591	38,854,539
1913	733,594	35,856,791	820,399	38,341,174
1914	721,090	38,211,760	772,156	35,479,741
1915	766,935	38,027,703	831,234	36,358,240
1916	875,780	46,908,093	824,222	42,179,160
1917	947,690	96,820,992	1,890,856	50,367,760
1918	1,053,510	113,991,123	2,114,382	65,204,825
1919	1,666,025	78,601,238	647,156	54,100,043
1920	1,377,700	53,946,146	692,306	42,203,211
1921	976,596	52,092,263	646,657	37,263,122
1922	1,291,135	60,606,728	678,751	34,291,675
1923	1,264,821	62,470,235	697,773	38,027,909
1924	1,796,105	58,662,997	727,499	38,185,313
1925	1,427,230	80,500,145	849,687	47,192,499
1926	1,222,993	85,315,284	934,809	56,455,662

Contains also movements between river points only.

[TABLE 9]

WATER REQUIREMENTS FOR OPERATION OF SALT WATER BARRIER WHEN FULLY DEVELOPED

(Quantities in Second Feet)

POINT SAN PABLO

	1	2	3	4	5	6	7	8	9	10	11	12
Fish Ladder	35	35	35	35	35	35	35	35	35	35	35	35
Industries, etc.	322	322	322	322	322	322	322	322	322	322	322	322
Gate Leakage	166	166	166	166	166	166	166	166	166	166	166	166
Oper. Locks	705	705	705	705	705	705	705	705	705	705	705	705
Evaporation	250	300	450	650	950	1200	1250	1170	1020	800	500	200
Irrigation	------	------	------	------	610	1680	2290	1910	1150	------	------	------
Flushing	200	200	200	200	200	200	200	200	200	200	200	200
Totals, S. F.	1678	1728	1878	2078	2988	4308	4968	4508	3598	2228	1928	1628

[TABLE 10]

WATER REQUIREMENTS FOR OPERATION OF SALT WATER BARRIER WHEN FULLY DEVELOPED

(Quantities in Second Feet)

ARMY POINT

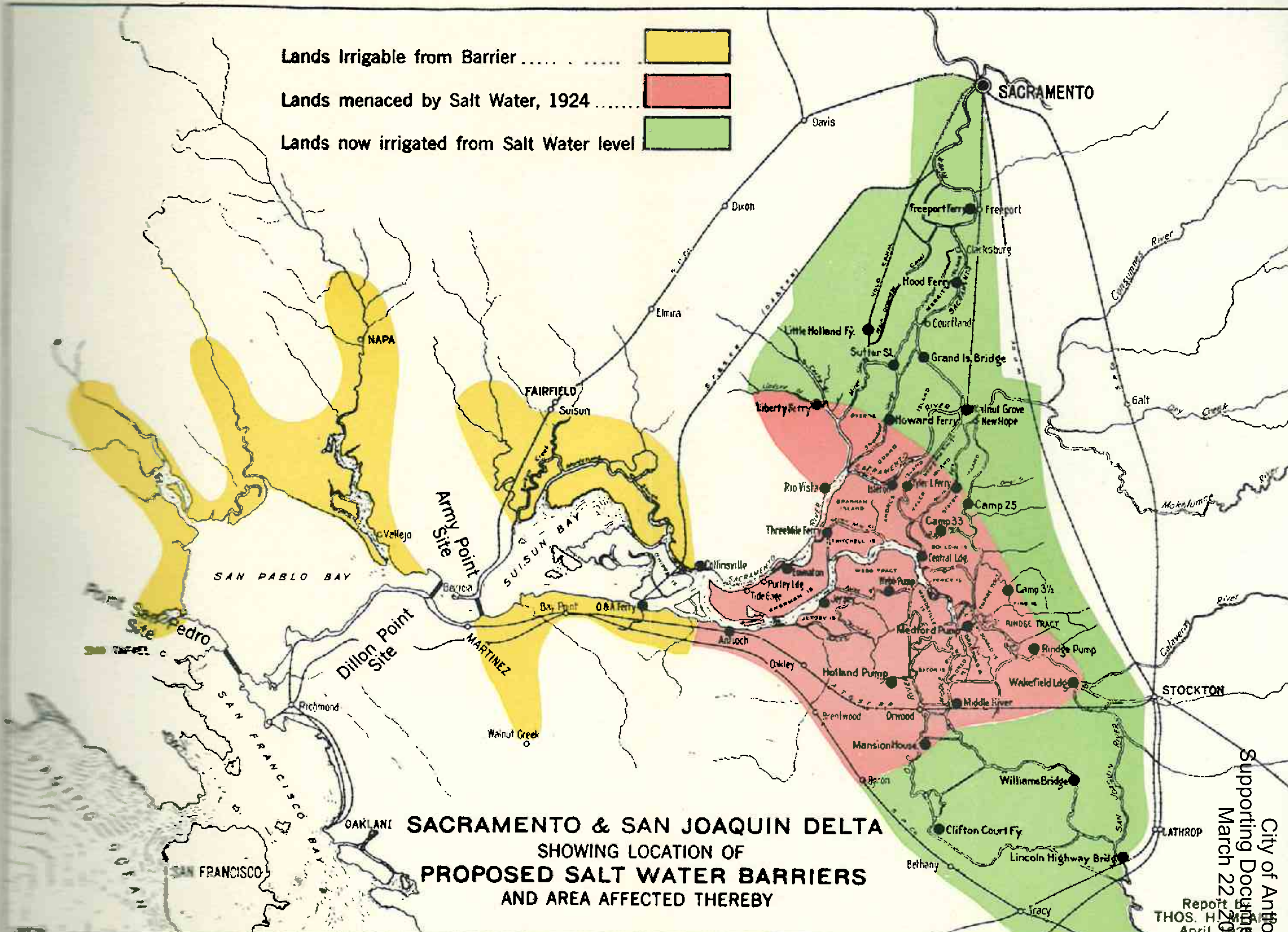
	1	2	3	4	5	6	7	8	9	10	11	12
Fish Ladder	35	35	35	35	35	35	35	35	35	35	35	35
Industries, etc.	155	155	155	155	155	155	155	155	155	155	155	155
Gate Leakage	166	166	166	166	166	166	166	166	166	166	166	166
Oper. Locks	246	246	246	246	246	246	246	246	246	246	246	246
Evaporation	110	146	200	288	422	530	555	522	455	355	222	89
Irrigation	------	------	------	------	380	1050	1430	1190	710	------	------	------
Flushing	200	200	200	200	200	200	200	200	200	200	200	200
Totals, S. F.	912	948	1002	1090	1604	2382	2787	2514	1967	1157	1024	891

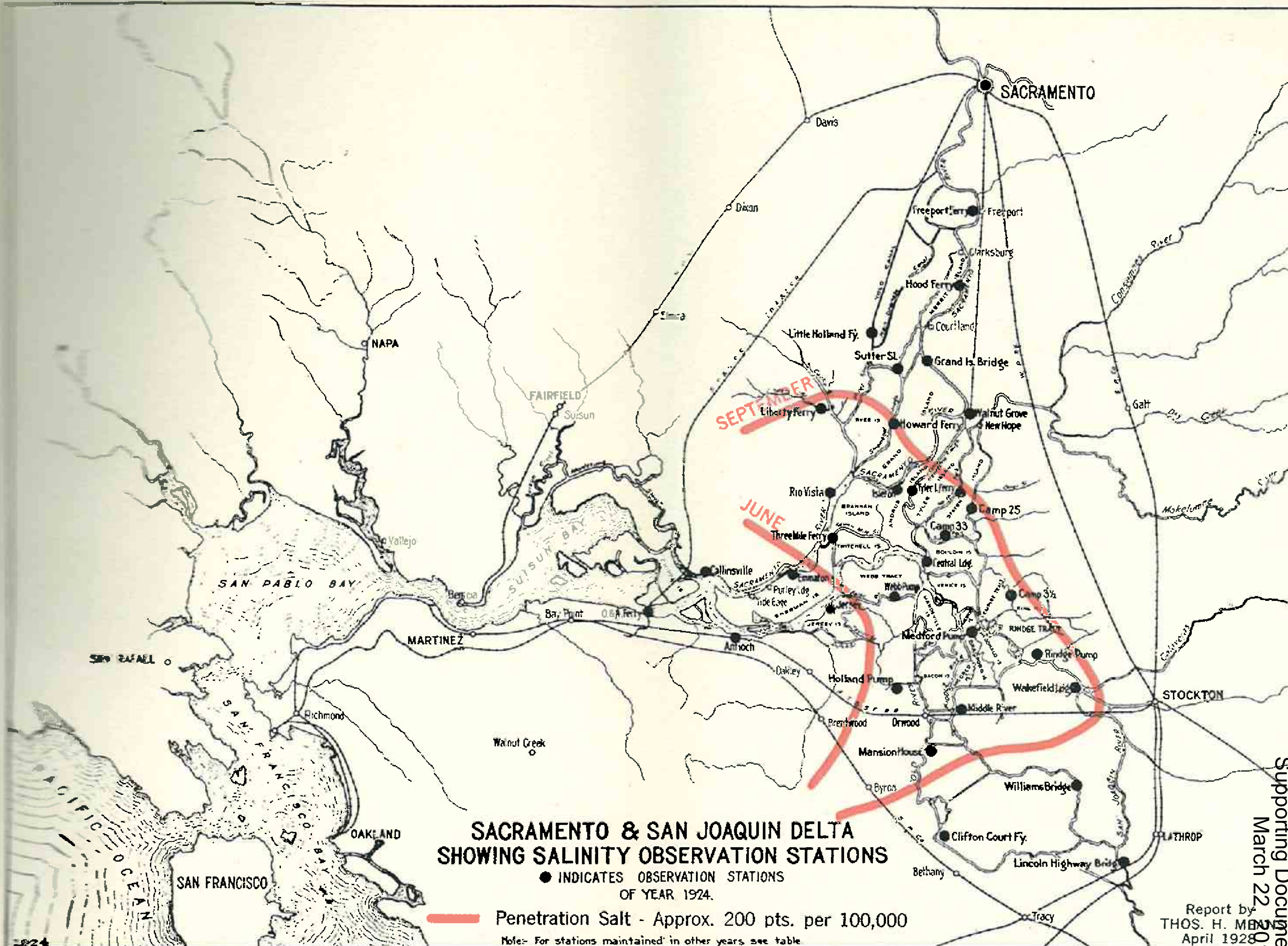
[TABLE 11]

WATER REQUIREMENTS ABOVE SALT WATER BARRIER
WHEN FULLY DEVELOPED

(Quantities in Acre Feet)

	Army Point	Point San Pablo
January	56,000	102,500
February	52,500	95,500
March	62,000	115,000
April	65,000	123,000
May	98,500	184,000
June	147,500	256,000
July	171,000	305,000
August	154,000	277,000
September	117,000	214,000
October	71,000	137,000
November	61,000	115,000
December	54,500	100,000
Totals	1,110,000	2,024,000


SACRAMENTO & SAN JOAQUIN DELTA
SHOWING LOCATION OF
PROPOSED SALT WATER BARRIERS
AND AREA AFFECTED THEREBY
Lands Irrigable from Barrier
Lands menaced by Salt Water, 1924
Lands now irrigated from Salt Water level
SACRAMENTO
Davis
Dixon
Elmira
FAIRFIELD
Suisun
NAPA
Vallejo
Army Point Site
Benicia
MARTINEZ
Dillon Point Site
SAN PABLO BAY
SUISUN BAY
SAN FRANCISCO BAY
Richmond
OAKLAND
SAN FRANCISCO
Walnut Creek
Bay Point
O&A Ferry
Collinsville
Antioch
Oakley
Brentwood
Orwood
Byron
Bethany
Tracy
LATHROP
STOCKTON
Galt
Freeport Ferry
Freeport
Clarksburg
Hood Ferry
Courtland
Little Holland Fy.
Sutter Sl.
Grand Is. Bridge
Walnut Grove
New Hope
Howard Ferry
Liberty Ferry
Rio Vista
Isleton
Camp 25
Camp 33
Central Ldg.
Camp 3½
RINDGE TRACT
Rindge Pump
Wakefield Ldg.
Medford Pump
Holland Pump
Middle River
Mansion House
Williams Bridge
Clifton Court Fy.
Lincoln Highway Bridge
Three Mile Ferry
Purley Ldg.
Tide Gage
SAN JOAQUIN RIVER
Calaveras River
Mokelumne
Cosumnes River
Dry Creek
Report
THOS. H.
April


SACRAMENTO & SAN JOAQUIN DELTA
SHOWING SALINITY OBSERVATION STATIONS
● INDICATES OBSERVATION STATIONS OF YEAR 1924.
Penetration Salt - Approx. 200 pts. per 100,000
Note:- For stations maintained in other years see table.
Report by
THOS. H. MEANS
April 1928
SEPTEMBER
JUNE
SACRAMENTO
Davis
Dixon
Elmira
NAPA
Vallejo
FAIRFIELD
Suisun
Benicia
MARTINEZ
Bay Point
O.&A. Ferry
Collinsville
Antioch
Oakley
Brentwood
Byron
Bethany
Tracy
LATHROP
STOCKTON
Galt
SAN PABLO BAY
SUISUN BAY
SAN FRANCISCO BAY
SAN FRANCISCO
OAKLAND
Richmond
Walnut Creek
SAN RAFAEL
PACIFIC OCEAN
Freeport Ferry
Freeport
Clarksburg
Hood Ferry
Courtland
Little Holland Fy.
Sutter Sl.
Grand Is. Bridge
Walnut Grove
New Hope
Howard Ferry
Liberty Ferry
Rio Vista
Isleton
Tyler Ferry
Camp 25
Camp 33
Threemile Ferry
Central Ldg.
Emmaton
Webb Pump
Camp 3½
Medford Pump
Rindge Pump
Holland Pump
Wakefield Ldg.
Middle River
Orwood
Mansion House
Williams Bridge
Clifton Court Fy.
Lincoln Highway Bridge
Cosumnes River
Mokelumne River
Dry Creek
Calaveras
San Joaquin River
1924

September 30, 2011

Via email to: DeltaPlanComment@deltacouncil.ca.gov

To: Phil Isenberg, Chair and Members of the Delta Stewardship Council (DSC)
Joe Grindstaff, Acting Executive Director, Delta Stewardship Council and DSC Staff

Re: City of Antioch comments on the Fifth Draft Delta Plan

The City of Antioch (Antioch) is pleased to submit its comments regarding the Fifth Draft Delta Plan. Our comments are presented in tabular format, with chapter, page and line references, to make it easier for DSC staff to review.

Included in our comments is an important issue that does not appear to be discussed in the DSC Delta Plan. We bring this to your attention in hopes that you will consider addressing it in the final Delta Plan and EIR. The issue is this: cumulative impacts to the Delta system as a whole are not discussed in the plan, nor is there discussion of creating an oversight or regulatory agency to monitor overall health of the Delta system. For example, who will track the combined impacts of the BDCP, Three Mile Slough and Old and Middle River gates projects on the Delta as a whole?

Different agencies track different Delta indicators, yet there is no scientific body that addresses the viability of the Delta as a whole. As projects come on line, and "adaptive management" is used for both ecosystem restoration and project operations, who will track the cumulative impacts of the combination of projects coming on line? It seems appropriate that the DSC address this in its Delta Plan, even to suggest a scientific body or group of agencies to take this 'system-wide' approach to track changes in/impacts to the overall health of the Delta. Without such oversight, another Delta crash could occur with no way to determine what went wrong, and what factors led to such a crash.

We very much appreciate the work that the DSC is doing and its ongoing efforts to obtain and incorporate public comments and input. We look forward to your review of our comments. Please call me at (925) 779-7025 if you would like more information or if you have additional questions.

Sincerely,

Phillip Harrington
Director of Capital Improvements/Water Rights
City of Antioch
P.O. Box 5007
Antioch, CA 94531-5007

Delta Plan Fifth Draft Comment from the City of Antioch 9/30/2011

Chapter	Page number	Line number	Text	Comment
Chapter 1				
	25 26	21-23 1-5	No water rights decisions or water contracts that directly or indirectly impact the Delta are made without consideration of the coequal goals...etc.	Does this indicate that the Delta Plan seeks to replace the current water rights system in California?
Chapter 3				
	54	27-31	Incorporation of Another Plan into the Delta Plan, Updating the Delta Plan	In cover letter to our comments regarding the Fifth Draft, dated 9.30.11--The Delta Plan does not mention nor address cumulative impacts to the Delta system from ongoing + new projects/programs. The effect of not taking a system-wide approach to policy is a Delta ecosystem or water quality/supply crash with no understanding about which event, program, or project caused it. Need a policy or recommendation to create a scientific oversight body to monitor the health of the Delta system-wide.
	55 56	13-14 1-7	...the Delta Reform Act requires the Council to establish and oversee a committee of agencies responsible for implementing the Delta Plan...	Is this committee only responsible for implementing the Delta Plan, or will it meet on an ongoing basis? Who is part of this committee, and will the Delta stakeholders and/or the public have a seat on this committee in addition to agencies?

	61	16-31	Discretionary Incorporation of Another Plan or Program into the Delta Plan	Again, no discussion of considering the cumulative impacts that an additional plan may add to the Delta System. Need a policy/entity to provide for oversight and monitoring.
	61	32-38	….Upon appeal the Council retains the authority to find the specific project inconsistent with the Delta Plan even if the Council finds that the larger plan is consistent with the Delta Plan.	This seems to indicate that a project under BDCP could be found inconsistent with the Delta Plan. Is this correct?
	62	20-23	…must file a consistency certification indicating only that he covered action is consistent with the BDCP. The Council retains the authority to find the covered action inconsistent with BDCP and therefore the Delta Plan.	This seems to indicate that BDCP only needs consistency with BDCP. The above comment from Page 61, lines 32-38 seems to contradict this. Please clarify.
Chapter 4				
	82	4-8	**WR P1** - A covered action to export water from, transfer water through or use water in the Delta is inconsistent with the Delta Plan if the covered action negatively impacts one or more of the coequal goals and one or more of the water suppliers that receive water from the Delta significantly causes the need for the covered action by failing to comply with one or more of the following	Would this indicate that the BDCP would be inconsistent with the Delta Plan if it significantly impacts one of the water suppliers (such as Antioch) causing the need for a covered action, such as a change in Antioch's diversion point, a water rights transfer or another regional solution driven by the impacts to Antioch's' water supply and quality?
	83	28-40	Evaluation of regional water balance	How are current water rights impacted by the water balance activity? Does this mean that water supply would be curtailed, despite holding pre-1914 water rights?

	84	34-37	**WR R5 –** SWRCB and/or DWR should require that proponents requesting a new point of diversion, place of use, or purpose of use that results in new or increased use of water from the Delta watershed should demonstrate that the project proponents have evaluated and implemented all other feasible water supply alternatives	Antioch may need to change its point of diversion or place of use, because of the impacts of the BDCP. Does this mean that such a mitigation would have to demonstrate that all other water supply alternatives have been evaluated, even though the change in diversion or place of use were a mitigation for a BDCP project? Also, do pre-1914 water rights holders have to comply with this?
Chapter 5				
	111	Map text	Since the 1960's our water system with upstream reservoirs and "other human-created management" has changed these patterns in two ways:	Insert "such as water exports" after "other human created management." Add a Number "3) Delta outflow was influenced by large outgoing flood flows that are now controlled."
	113	10-12	**ER P1** Prior to the establishment of revised flow objectives criteria identified above, the existing Bay-Delta Water Quality Control Plan objectives shall be used to determine consistency with the Delta Plan.	The current BDCP operation alternatives contain a move of water quality compliance point from Emmaton to Three-Mile Slough. This is will not be in compliance with the existing WQCP.

	114	1-7	Determine that a covered action that would increase the capacity of any water system to store, divert, move, or export water from or through the Delta would not be consistent with the Delta Plan until the revised flow objectives are implemented. Recommend that the State Water Resources Control Board cease issuing water rights permits in the Delta and the Delta watershed (or, if the absence of flow criteria is specific to one or more of the major tributaries, then the recommendation could be focused on the impacted areas).	Would these apply to any petition for change of use including a petition by BDCP to SWRCB for change of compliance point?
	121	24-26	**ER R3** – State and Federal fish agencies….should complete "ongoing negotiations" toward a habitat agreement with water supply agencies	To what "ongoing negotiations" is this referring to-- BDCP? If so, state here. If not, clarify the scope of projects you are referring to here.
	122	19-32	Controlling stressors is difficult or impossible…..discussion about the lack of science about cause and effect.	Again, the Delta Plan needs a policy or recommendation for determining the cumulative impacts of stressors and projects in the Delta watershed.

	124	25-34	**ER R7 –** "...For example, workshops would consider options for varying salinity to reduce impacts of nonnative invasive species while providing overall ecosystem benefits and minimally disrupting water supply."	Suggest deleting "minimally." The Delta Plan discusses options for varying salinity throughout the Plan. Depending upon the location and the conditions, allowing variable salinity could have major impacts on in-Delta M&I water supply/quality. Increased salinity would also impact recreational boating and fishing in the Delta. Recreational boating/fishing are the #1 "recreational" revenue producers for the Delta, according to the Economic Sustainability Plan draft (8.9.11). Boaters use the Delta for its fresh water environment; numerous issues related to boat and marina maintenance would deter this recreational use.
	127	19-37	"Progress toward restoring in-Delta flows to more natural flow patterns to support a healthy estuary. Metrics: results from hydrological monitoring and hydrodynamic modeling ..."	This performance measure is very vague; more detail is required, including defining what constitutes a natural flow pattern (which should be tied to pre-1918 conditions).

Chapter 6				
	133	19-21	To support a more resilient and healthy ecosystem, salinity patterns should be consistent with a more naturally variable hydrograph with high-quality river inflows.	Delta outflow is missing here and is a crucial factor for attainment of the co-equal goals of water quality in the Western Delta as well as for species such as Delta Smelt. Add outflow. Add that the salinity variability historically occurred farther west than it does today (i.e., salinity was more variable historically, but the system was also far fresher than it is today).
	136	35-36	This freshwater-saltwater gradient has changed over the past 150 years because 35 of landscape modification, water management, and climate variability	"Water management" should be changed to "exports, diversions, and other water management." Exports and diversions need to be inserted wherever "water management" occurs in the Delta Plan
	136	41-44	...Even with these measurable shifts in the salinity gradient caused by diversion, storage, and conveyance of water, the primary driver of salinity variability in the western Delta and Suisun Marsh continues to be the amount of precipitation in the watershed.	This is not correct on its face. "Delta outflow" is the major factor for salinity and variability in the western Delta. Historically, fresh water was present in the western Delta even during dry years (see CCWD historic salinity report). Further, the channelization of the Delta has changed the system's response to precipitation, increasing the amount of salinity intrusion (CCWD Historical Salinity Report, 2010).

	137	15-20	..The endangered Delta smelt (*Hypomesus transpacificus*) show a preference for the LSZ. Their distribution during most of the year is centered near X2 (Nobriga et al. 2008). The position of X2 is also correlated with the abundance of several estuarine fish and invertebrates such as the bay shrimp (*Crangon franciscorum*) and longfin smelt (*Spirinchus thaleichthys*). That is, higher outflows (smaller X2 values) are correlated with greater abundance of longfin smelt and bay shrimp (Kimmerer 2004).	Given that Delta Smelt are dependent upon low salinity zone in the western Delta, how will this freshwater zone be preserved, given the BDCP change to outflows, and move of compliance points from Emmaton to Three Mile Slough, which will allow less flow and higher salinity?
	137	21-27	.. The evidence is strong, however, that the Delta was a freshwater ecosystem in the western Delta for 2,500 years before human modification in the nineteenth and twentieth centuries (Malamud-Roam and Ingram 2004).	Antioch agrees with this statement

	137 138	25-27 1-2	Dredging of channels, reduction in the amount of tidal marsh, and construction of levees have changed the Delta salinity gradient by increasing the strength of tides in the Delta, increasing connections between channels, and reducing the moderating effects of wetlands and floodplains on outflow. Consequently, simply allowing more variability in Delta outflow will not produce the same salinity gradient patterns that existed before development.	Add "water exports" as a cause of salinity gradient change in the first sentence. Exports (since the early 1900s) have dramatically changed the salinity gradient. Note Antioch's comment letter to Isenberg, Grindstaff et al regarding impacts of BDCP, dated 11/15/10 We agree that "simply allowing more variability in Delta outflow will not produce the same salinity gradient patterns that existed before development."
	138	17-21	Water quality at the State Water Project (SWP) and Central Valley Project (CVP) export pumps in the southern Delta, while usually meeting all applicable standards for municipal and agricultural use, is significantly higher in salinity than Sacramento River inflow to the Delta. Allowing salinity to vary in a way that might benefit native fish species could impact agricultural and municipal uses of Delta water at SWP, CVP, and other Delta diversion points. Elevated salinity reduces crop yields (Hoffman 2010) or, if high enough, makes water unusable for agricultural purposes.	The statement implies that salinity variations would benefit native species; however, as noted in CCWD Historical Salinity study report (2010), while the Delta did experience greater variability in the past, it did so within a far fresher environment than currently exists. Thus, it is not clear that greater salinity variation would benefit native species. We concur about allowing salinity to vary could have negative impact on AG and M&I water quality. Please add that recreational boating and fishing would also be impacted.

	139	26-30	Sources of these drinking water constituents of concern include natural processes, such as tidal mixing of seawater into the Delta, and the flux of water and organic matter from wetlands, as well as urban runoff, agricultural runoff, and municipal wastewater discharge._Pathogenic protozoa, bacteria, and viruses are also present in Delta waters and are a disease risk for both drinking water and body-contact recreation.	Add "water exports" to the non-natural causes listed in this sentence, as increased exports increase salinity in drinking water in the Western Delta. One of the primary factors for tidal mixing of seawater into the Delta has historically been water exports and large diversions from the north (Means Report, 1928 about changing conditions in the 1900s due to increased exports and recent DWR data about exports and salinity increase.)
Chapter 8				
	191	33-34	Boating and water-dependent recreation represent the highest percentage of existing recreation activities in the Delta. In the California Department of Boating and Waterways' 2002 study, annual boating-related visitor days to the Delta were estimated at 6.4 million in 2000, with a 1 projected growth to 8 million visitor days by 2020 (DBW 2002).	Delta Economic Sustainability Plan concurs with this. Increased salinity or increased variability in salinity will impact boaters, species and M&I. Boaters use the Delta for its fresh water environment. Numerous issues related to boat and marina maintenance would deter this #1 recreational economic factor in the Delta.

	197	28-31	**DP R1** The Economic Sustainability Plan should include, but not be limited to….. • The economic goals, policies, and objectives in local general plans and other local economic efforts, including recommendations on continued socioeconomic sustainability of Delta agriculture and its infrastructure to support the proposed economic strategies and legacy communities in the Delta	Suggest change to read: "The economic goals, policies, and objectives in local general plans and other local economic efforts, including recommendations on continued socioeconomic sustainability of Delta agriculture and its infrastructure, *as well as other beneficial use of public trust resources (such as water quality for M&I, boating and recreation to* support the proposed economic strategies and legacy communities in the Delta"
Chapter 9				
	208	17-23	Urgent expenditures for water reliability and ecosystem protection: Immediate steps should be taken to protect the existing Delta water export system from flood risks, and protect ecosystem improvements being implemented pursuant to existing mitigation commitments of the SWP and the Central Valley Project (CVP). Those immediate needs are discussed in the various chapters of the Delta Plan. These recommendations are in addition to other ongoing efforts that should continue to be funded. Examples include implementing the federal biological opinions, funding levee subventions, funding science, and many more.	This indicates that only water export-system expenditures are considered urgent. What about levees in the Western Delta, that protect the whole system? Suggest change to read: "Immediate steps should be taken to protect the existing Delta "water supply system" ~~export~~ from flood risks, and protect ecosystem improvements being implemented pursuant to existing mitigation commitments of the SWP and the Central Valley Project (CVP).

	211	20-21	**FP R6** - The Legislature should authorize the Delta Stewardship Council to develop reasonable fees 20 for beneficial uses and reasonable fees for those who stress the Delta ecosystem	Please clarify: What level of and type of stress is indicated by the statement "for those who stress the Delta ecosystem?" Broadly interpreted, this could mean a boater, a fisherman, a hiker, as well as current M&I user.
	212	10-18	**FP R12** - Establish a statewide public goods charge (or broad-based user fee) for water. The Legislature 10 should create a public goods charge (similar to the energy public goods charge created in 1996) 11 on urban water users and agricultural users. This charge could provide for ecosystem costs that were once paid with general obligation bonds, or could be used for State water management costs such as developing the California Water Plan Update or science programs	This indicates that ecosystem restoration mitigation projects required by the BDCP would be paid for by impacted stakeholders in the Delta. This is a "double hit" cost impact to in-Delta agriculture and other in-Delta stakeholders, who would therefore be required to pay for BDCP's mitigation credit projects as well as suffer the impacts of the BDCP project itself.

C.7 Conclusions

C.7.1 Summary of Changes in Flow

The preliminary proposal would result in very minimal changes in upstream flows or reservoir operations. As such, there are only a few instances in which changes to the environment and related effects on fish may occur. Flow-related temperature effects on spring-run Chinook salmon and green sturgeon spawning and egg incubation are described in Section C.7.2. In the Delta, flows in and around the San Joaquin River and south Delta would improve, reflecting the reduced use of the south Delta export facilities. However, the flow patterns in the north Delta could be altered by operations of the new north Delta export facilities and the increased inundation of the Yolo Bypass. These operational changes will reduce some Sacramento River flows, resulting in reduced flows in Sutter, Steamboat, and Georgiana Sloughs and the DCC. Similarly, the reduced flows in the Sacramento River would slightly reduce flows in Threemile Slough. These changes in flow patterns in the north Delta can affect the migration and passage of fish through and within the Delta, as described in Section C.7.2. The changes in Delta flows are not expected to result in any substantial changes in turbidity or DO, as described below. However, the changes in Delta operations under the preliminary proposal related primarily to the new north Delta intake could have effects on salinity in some locations, as described below. In most instances, these changes in salinity are compounded by the effects of restoration activities that would occur as part of the preliminary proposal and sea level rise. The following sections provide a discussion of the general trends of changes in flows throughout the Plan Area. More detailed results are provided in Attachment C.A and are the basis for the biological results presented in Section 7.2.

C.7.1.1 Upstream Flows

The CALSIM results indicate that there would be little to no change in how reservoirs are operated. The largest changes to reservoir operations result from changes in runoff and inflow caused by climate change unrelated to the preliminary proposal. Coldwater pool management would be challenging for the CVP facilities. Oroville storage generally would be higher under the PP scenarios and would exhibit greater flexibility to adapt to future changes.

In general, the PP would increase carryover storage (end-of-September storage, often the lowest each year) compared to the EBC scenarios. However, CVP and SWP operations are expected to change operations to address the increased outflow needs caused by sea level rise and climate change. These results suggest that the management of storage for the coldwater pool (May storage is an indicator) would be increasingly difficult in the future, despite the fact that the PP would have increased carryover. The frequency of the end-of-September storage falling below 2,000 thousand acre-feet (taf) would increase by about 10% under both the PP and EBC in the LLT. Considerable adaptation measures would need to be implemented on the upstream operation of the CVP to manage the coldwater pool under the extreme sea level rise and climate change by 2060. Operation of the PP would lessen these challenges, but the effect of climate change and sea level rise would overwhelm these improvements.

These general conclusions are based on the CALSIM data, which are summarized below for each reservoir and river, and the actual operational constraints of the CVP and SWP. Because the CALSIM model uses a monthly time step, it does not necessarily capture the day-to-day operations that would respond to potential adverse effects, such as temperature changes and minimum flow and storage requirements. However, because the preliminary proposal is not expected to require substantial changes in upstream CVP and SWP operations, the CALSIM results indicate considerable monthly changes are not expected to occur in reality. Rather, DWR and U.S. Department of the Interior, Bureau of Reclamation (Reclamation) reservoir operators would continue to operate the reservoirs and associated flows on a daily basis in a manner that meets flow, storage, and temperature requirements.

C.7.1.2 Delta Flows

The primary changes in Delta operations result from the north Delta intakes and the increased flows into the Yolo Bypass at the Fremont Weir. These changes generally divert water from the Sacramento River into either the new intake or the Yolo Bypass, reducing flows in Sutter, Steamboat, Threemile, and Georgiana Sloughs; in the DCC; and at Rio Vista. Reductions in south Delta pumping that are possible with the north Delta intakes increase OMR flows and San Joaquin River flows at Antioch by the amount of the reduced pumping. While climate change may affect flows in the San Joaquin, Mokelumne, and Cosumnes Rivers, no effects of the preliminary proposal are expected in the Delta channels connected to these river inflows. A summary of changes at each Delta location is provided below. However, these changes reflect the general trends and not necessarily the outer bounds of potential changes that could occur across water-year types and months within those water years. The effects analysis used detailed modeling results to determine the biological responses to specific daily, monthly, and water year–type changes. These are reported in the *Results* section above.

C.7.1.2.1 Sacramento River Flows at Freeport

The Sacramento River flow at Freeport provides the largest Delta inflow and represents the water available for diversion at the proposed north Delta intakes. The average annual inflow at Freeport was reduced by about 650 taf (up to 4%), primarily as a result of the increased Fremont Weir spills into the Yolo Bypass that would occur under the preliminary proposal. Similarly, PP_ELT and PP_LLT monthly median flows at Freeport were similar to EBC1 but were shifted in some months as a result of the increased spills at the Fremont Weir and other changes in upstream reservoir releases, as discussed above.

The Freeport median flows were similar in October, November, and December for the EBC1 and PP cases. The Freeport median flows in January, February, and March for the PP cases were about 3,000 cfs less than EBC1 flows, reflecting the increased spills at the Fremont Weir into the Yolo Bypass. The April and May median flows at Freeport were similar for the PP cases and EBC1 conditions. The June median flows were increased for the PP cases. The Freeport median flows for the PP cases in July, August, and September were reduced by about 3,000 cfs compared to EBC1 flows because of changes in upstream reservoir releases. The preliminary proposal north Delta intakes allowed higher exports in April, May, and June and subsequently allowed reduced reservoir releases and reduced exports. The PP cases had inflows and exports that were distributed more evenly during the highest agricultural demand period of April through September.

C.7.1.2.2 San Joaquin River Flows at Vernalis

The only changes in the San Joaquin River flows are caused by the assumed climate change effects on reduced San Joaquin River (above Friant Dam) inflows and reduced tributary inflows. No changes from preliminary proposal operations were simulated.

C.7.1.2.3 Yolo Bypass Flows to the Delta

The Yolo Bypass flow is nearly identical to the Fremont Weir spills, with the addition of the Cache Creek and Putah Creek flows entering the bypass in months with relatively high runoff. Although the preliminary proposal ELT and LLT cases allow some additional flows into the Yolo Bypass at the Fremont Weir, the monthly sequence of Yolo Bypass flows was very similar. A few more months have flows of 3,000–5,000 cfs (notch capacity), and the high-flow months have slightly more flow (5,000 cfs).

C.7.1.2.4 Mokelumne River and Cosumnes River Flows to the Delta

The monthly inflows from the Mokelumne River near Thornton, just below the Cosumnes River, are very low during the summer months. These flows were nearly identical for all CALSIM cases. Most Cosumnes River runoff enters the Delta, and the Mokelumne River is highly regulated by Pardee and Camanche Reservoirs. The minimum flows below Woodbridge Dam are specified based on runoff, and reservoir spills are rare. There were no effects of the preliminary proposal on these river flows.

C.7.1.2.5 San Joaquin River Diversions to Old River

The preliminary proposal would not result in changes in the San Joaquin River flows at Old River, but some changes are expected as a result of climate change. The median head of Old River flow for December through May was about half of the San Joaquin River flow at Vernalis. The median flows in June through September were about 40% of the San Joaquin River flow at Vernalis because of the effects of the south Delta rock barriers. The annual average head of Old River diversion flow was nearly the same for all six CALSIM cases and was equal to about half of the San Joaquin River flow.

C.7.1.2.6 Old and Middle River Flows

The CALSIM modeling assumed that some OMR reverse flow restrictions would apply for each of the applicable months (December through June). The restrictions were assumed to vary somewhat with runoff conditions. The assumed restrictions were held constant for each of the EBC1 cases, the three EBC2 cases, and the two preliminary proposal cases. Because negative OMR flow is toward the south Delta pumps, the greatest negative values indicate higher pumping. The minimum values indicate the maximum pumping from the central Delta. For example, the October and November minimum flows for EBC1 were -10,000 cfs. The October and November median flows were -8,000 cfs. However, there are no OMR flow restrictions in October and November. The EBC1 December minimum flow was -9,600 cfs, but the median flow was -5,871 cfs (the assumed OMR limit in 30% of the years). This suggests that the OMR limits were reducing the December exports to this level in several of the years. The January through March and June minimum flows were -5,000 cfs because the assumed OMR limits were restricting pumping to this level in many of the years in these months. The minimum flows in April and May were higher than the limit of -5,000 cfs because the NMFS exports/San Joaquin River ratio that applies in April and May was reducing the exports more than the OMR limits. EBC1 flows in July through September were -11,000 to -10,000 cfs, and median flows were -10,000 to -9,000 cfs.

The preliminary proposal ELT and LLT cases shifted pumping from the south Delta to the north Delta intakes and thereby increased the OMR flows (reduced negative OMR flows). The median OMR flows for the preliminary proposal ELT and LLT cases were about 2,000 cfs higher in October and November; about the same in December; 2,000 cfs higher in January; 5,000 cfs higher in February; 3,500 cfs higher in March; 1,500 cfs higher in June; 6,000 cfs higher in July; 6,500 cfs in August; and 4,500 cfs higher in September.

C.7.1.2.7 Sutter Slough and Steamboat Slough Flows

Sutter and Steamboat Sloughs divert about 40% of the Sacramento River flow. The monthly median diversion flows into Sutter and Steamboat Sloughs were similar for the EBC1 case and the three EBC2 cases because the Sacramento River flows were similar. The median diversions into Sutter and Steamboat Sloughs were lower for the PP_ELT and PP_LLT cases because the north Delta intakes reduce the Sacramento River flow at Sutter and Steamboat Sloughs. The median diversions in October, April, May, and June were about the same for the baseline and the preliminary proposal cases. The median diversions were reduced by 1,000 cfs in November, July, and September; 2,000 cfs in January and August; and 4,000 cfs in February and March. The reductions in the Sutter and Steamboat Slough diversions were about 40% of the simulated north Delta intake diversions. The annual average diversions into Sutter and Steamboat Sloughs were about 6,500 taf (42% of the Sacramento River flow at Freeport) for the EBC1 case and three EBC2 cases, and were reduced to about 5,500 taf (36% of the Sacramento River flow at Freeport) for the two preliminary proposal cases.

C.7.1.2.8 Delta Cross Channel and Georgiana Slough Flows

Similar to Steamboat and Sutter Sloughs, the PP_ELT and PP_LLT cases for DCC and Georgiana Slough had reduced monthly median diversion flows because the north Delta intakes reduced the Sacramento River flow. The annual average diversions into the DCC and Georgiana Slough were about 3,750 taf (24% of the Sacramento River flow at Freeport) for the EBC1 case and three EBC2 cases, and were reduced to about 3,150 taf (21% of the Sacramento River flow at Freeport) for the two preliminary proposal cases.

C.7.1.2.9 Sacramento River Flows at Rio Vista

The minimum flows in September through December for Rio Vista (3,000–4,500 cfs, depending on water-year type) were generally satisfied. The EBC1 monthly median flows were about 5,500 cfs in October; 7,500 cfs in November; 12,500 cfs in December; 22,000 cfs in January; 29,000 cfs in February; 23,000 cfs in March; 13,000 cfs in April; 10,000 cfs in May; 6,500 cfs in June; 10,500 cfs in July; 8,500 cfs in August; and 6,500 cfs in September. The median flows at Rio Vista for the three EBC2 cases were similar because the Yolo Bypass and Sacramento River inflows were generally the same. The median monthly Rio Vista flows were reduced in the months when the north Delta intake diversions were simulated for the PP_ELT and PP_LLT cases. The reduced Rio Vista flows were generally about the same as the north Delta intake diversions. The annual average Sacramento River flows at Rio Vista were about 14,000 taf for the EBC1 case and three EBC2 cases, and were reduced to about 12,000 taf for the PP_ELT and PP_LLT cases.

C.7.1.2.10 Threemile Slough Flows

The Threemile Slough flows are about 3% of the Rio Vista flows and were reduced slightly for the preliminary proposal cases because the Rio Vista flows were reduced by the north Delta intake diversions. The annual average Threemile Slough flows were about 1,000 taf for the EBC1 case and the three EBC2 cases, and were reduced to about 750 taf for the two preliminary proposal cases.

C.7.1.2.11 San Joaquin River Flows at Antioch

San Joaquin River flows at Antioch were increased in the PP_ELT and PP_LLT cases because the reduction in south Delta exports will increase OMR and San Joaquin River flows by the same amount. For the preliminary proposal cases, the monthly median flows were about 0 cfs in October and November, and were reversed to -2,000 cfs only in December. The San Joaquin River flows were about 1,500 cfs in January; 8,500 cfs in February; 6,500 cfs in March; 3,000 cfs in April; 2,500 cfs in May and June; 1,000 cfs in July; 500 cfs in August; and 150 cfs in September. The summer periods of reverse San Joaquin River flow were generally eliminated by the preliminary proposal north Delta intake diversions.

C.7.1.2.12 Delta Outflow

The CALSIM-simulated Delta outflow is the sum of all the upstream and Delta operations, and it is the major link with salinity in the Delta and with the X2 position. Delta outflow requirements often limit the Delta exports, so the simulated Delta outflow for many months is equal to the minimum Delta outflow requirement for each month. The EBC1 case did not include the BiOp Fall X2 requirements, so the required Delta outflow was controlled by the D-1641 objectives. The annual average outflow required for EBC1 (D-1641) was 4,250 taf. The three EBC2 cases included the BiOp Fall X2 requirements, and the average annual required outflow was about 5,000 taf for EBC2, about 5,250 taf for EBC2_ELT, and about 5,750 taf for EBC2_LLT. The BiOp Fall X2 requirements (intended for wet and above normal years) raised the annual average required outflow for EBC1 by about 750 taf. The EBC2_ELT and EBC2_LLT cases had even higher required outflows caused by changes in the outflow required to meet X2 because of sea level rise and habitat restoration effects on salinity intrusion.

The monthly median outflows simulated by CALSIM for each modeling scenario are shown in Table C.7-1. About half of the months had excess Delta outflow compared to the outflow requirements, but the outflow in most of these months likely was controlled by the maximum allowed export/inflow (E/I) ratio.

Table C.7-1. Average Annual and Monthly Mean Outflows for Each of the Six CALSIM Scenarios

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Average Annual Outflow (taf)	15,533	15,743	16,157	16,282	14,875	15,210
Monthly Median Outflow (cfs)						
January	22,361	21,730	21,342	21,903	21,277	22,074
February	36,554	35,578	35,846	37,339	36,181	35,855
March	26,890	26,801	25,701	25,784	24,828	24,486
April	18,921	18,804	18,708	18,283	12,470	13,037
May	15,899	15,655	13,911	12,806	11,352	11,400
June	7,243	7,249	7,243	8,336	8,086	9,290
July	8,000	8,000	8,000	8,520	8,000	8,000
August	4,000	4,000	4,000	4,112	4,000	4,000
September	3,610	3,621	3,659	3,430	3,000	3,000
October	4,000	4,403	5,425	7,813	4,000	9,234
November	5,088	10,313	9,844	10,415	4,500	4,500
December	8,086	7,696	8,666	9,156	8,867	9,219
taf = thousand acre-feet.						

The monthly median outflows for the PP_ELT and PP_LLT cases were similar (within 1,000 cfs) to the EBC1 median outflows in October through February; 2,000 cfs less in March; 6,000 cfs less in April; 4,000 cfs less in May; and similar in June through September. The annual average Delta outflow for the EBC1 case was 15,500 taf. The annual average outflows were 14,875 taf for the PP_ELT case and 15,200 taf for the PP_LLT case.

C.7.1.3 Salinity

Salinity is included in this appendix to assess the potential for changes to habitat as a result of changes in flows that may cause changes in salinity. (Salinity as a drinking water quality parameter is addressed in the BDCP EIR/EIS.) The preliminary proposal allows more salt into the western Delta because of increased tidal mixing associated with the addition of tidal marsh areas and reduced Delta outflow. Substantial increases in salinity at Emmaton and moderate increases at Jersey Point and Rock Slough caused by the preliminary proposal are generally attributable to the reduction in Sacramento River flows in these areas. However, slight reductions in average annual salinity at Threemile Slough are expected as a result of major salinity decreases in July and August caused by higher outflows. As the preliminary proposal is implemented and more tidal marsh is restored, salinity effects at these locations intensify. At Emmaton under PP_LLT, the largest increases in salinity occur from May to September, while there are minimal changes in salinity from October through April. Jersey Point and Rock Slough are also expected to have additional increases in salinity in the LLT as a result of restoration activities. The annual average salinity at Threemile Slough is further reduced in the LLT because of substantial salinity reductions in October and November resulting from higher Sacramento River flow.

Salinity can be controlled somewhat by Delta outflow. Higher Delta outflow moves the salinity gradient west and lowers the X2 (decreases the distance from the Golden Gate). Under the PP scenarios, X2 moves upstream (lower outflow) in some months, with the reduced inflows or higher exports that are allowed with the north Delta intake. However, the PP scenarios will meet the required D-1641 X2 locations from February through June and the minimum Delta outflows, as described above and shown in Table C.7-2.

Table C.7-2. Summary of the Location (km from the Golden Gate Bridge) of X2 under each CALSIM Scenario

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	67.1	51.7	47.3	47.2	47.2	47.2	47.3	48.5	49.1	56.2	66.0	63.5
Max	94.7	93.9	92.2	89.7	86.9	83.3	83.2	87.4	90.5	91.2	91.5	92.6
Avg	88.5	86.3	77.9	67.6	60.7	60.7	63.4	67.5	74.6	80.4	85.2	86.4
B. PP_ELT												
Min	72.8	52.2	47.7	47.6	47.6	47.7	47.7	49.3	51.0	62.3	74.7	71.4
Max	93.1	92.6	92.4	90.1	86.8	82.3	83.2	87.1	90.2	90.5	92.1	93.5
Avg	89.0	86.8	78.3	68.3	62.1	62.4	66.7	71.8	77.0	81.6	86.5	88.5
C. PP_LLT												
Min	73.8	54.6	48.8	48.7	48.7	48.7	49.0	51.6	54.8	69.9	83.4	79.3
Max	92.4	94.3	91.6	90.1	85.7	83.5	84.5	89.1	92.1	91.6	91.9	92.7
Avg	85.7	85.1	79.7	68.9	63.2	63.8	68.0	73.7	78.9	83.2	87.5	89.2
D. EBC2												
Min	67.3	51.7	47.3	47.2	47.2	47.2	47.3	48.5	49.3	57.1	67.3	65.8
Max	94.6	93.4	92.2	87.2	83.2	82.3	82.5	87.2	90.2	90.9	90.8	92.4
Avg	84.1	82.3	76.3	67.4	60.8	61.0	63.6	67.8	74.7	80.4	85.2	82.5
E. EBC2_ELT												
Min	69.5	52.4	47.8	47.6	47.6	47.7	47.9	49.8	51.5	62.1	73.6	70.9
Max	93.9	94.4	93.6	90.4	87.0	82.7	83.1	87.6	90.2	90.8	90.9	92.6
Avg	84.1	82.3	76.6	67.9	61.7	61.9	64.6	68.9	75.9	80.3	85.1	82.7
F. EBC2_LLT												
Min	72.2	55.4	50.0	49.6	49.6	49.5	50.0	53.1	55.7	71.4	81.2	73.9
Max	94.6	94.7	94.0	90.4	87.3	83.8	84.6	88.7	90.9	90.9	92.1	94.3
Avg	83.7	82.7	78.2	69.4	63.5	63.7	66.5	71.4	77.6	80.8	85.8	83.4

The three EBC2 cases, which included BiOp Fall X2 requirements in September through November of about half of the years (wet and above normal), had corresponding reduced X2 values in the 50–90% cumulative values. The changes in the monthly X2 ranges or in the monthly median values were relatively small because the monthly range in outflows remained similar for each of the EBC1 and EBC2 baseline cases. The preliminary proposal cases allowed some of the X2 positions to move upstream (lower outflow), with the higher exports that were allowed in some months with the north Delta intake. The required D-1641 X2 locations from February through June and the minimum Delta outflows were satisfied by the preliminary proposal cases, although CALSIM results reported above may be based on relaxations of the requirements in certain months.

C.7.1.4 Turbidity

Firm conclusions regarding changes in turbidity in the Plan Area are difficult to make. Uncertainty in sediment supply in the future is high because of factors such as the maturation schedule of habitat restoration within ROAs. In addition, the potential use of fill-in materials or wind breaks in the ROAs to reduce wind-driven sediment resuspension also could greatly affect turbidity. These and other factors limit the feasible scope of the analysis.

The analysis focused on whether the different subregions would become erosional, which would increase turbidity, or depositional, which would decrease turbidity. The analysis also evaluated whether seasonal wind resuspension within ROAs is likely to be greater with the preliminary proposal, thereby increasing turbidity. Factors such as submerged aquatic vegetation (SAV), benthic filter feeders, organic materials, and the potential substantial effects on the critical shear stress of erosion from changes in benthic algae and macrofauna have not been considered in the present analysis of turbidity because of a lack of data, a lack of modeling tools, or both.

The Delta will remain regionally depositional in the LLT time frame, in both EBC and PP scenarios, although the location of the depositional regions will differ. The effects of sea level rise will depend on the balance between sediment supply from the watersheds and the rate of sea level rise, so it is unclear whether sediment supply will be sufficient to maintain the current extent of tidal marsh. The initial effect of the ROAs in the PP is to decrease sediment supply downstream, but the longer-term effects are uncertain as the ROAs reach a dynamic equilibrium.

Under the PP, the North Delta subregion will receive less sediment because of increased flows through the Yolo Bypass, but this may not be a large enough factor to differentiate these effects from the overall effects due to sea level rise and climate change alone in the LLT under existing conditions. The Cache/Yolo Bypass–region ROAs will become depositional with sediment that otherwise would be carried down the Sacramento River. While the ROAs have the potential to increase water clarity in existing open water areas such as Liberty Island at least initially, wind resuspension of unconsolidated sediment during the summer is likely to decrease water clarity in the region seasonally. The West Delta ROA will accrete sediment, resulting in a local increase in water clarity in combination with decreased supply due to sediment deposition in the Cache/Yolo region. However, decreased sediment supply could result in erosion and a decrease in water clarity, leaving a mixed outcome for this region. The East Delta subregion is likely to experience increased water clarity due to the ROAs, both because of decreased flow through Georgiana Slough and because of deposition in the East Delta ROAs of the small amount of sediment originating from the Mokelumne and Cosumnes Rivers. The effect of seasonal winds will be minor because the ROAs are not large in the East Delta. The South Delta ROA consists of large open water areas that (barring establishment of SAV such as *Egeria densa*) likely will experience decreased water clarity due to wind resuspension in the summer. However, deposition in the ROAs also could increase water clarity, resulting in an overall mixed outcome.

The effect of the Suisun Bay subregion ROAs, both locally and due to effects from upstream ROAs, is complicated. Suisun Bay is currently erosional and the opening of ROAs upstream is likely to increase this erosion. If Suisun Bay continues to deepen and intertidal regions are lost, wind waves will become less effective at suspending sediment, so erosion rates may slow even in the presence of reduced sediment supply. The new ROAs may exert a local decrease in water clarity from seasonal resuspension due to wind. However, predicting the balance between the depositional environment in the ROAs and increased regional erosion is very complicated, so the overall result for water clarity is uncertain. The ROAs in Suisun Marsh likely will be depositional because of local sediment supply, resulting in local increases in water clarity. The effects of wind resuspension in decreasing water clarity likely will be limited to the larger ROAs in this region, depending on wind direction.

The effects of turbidity on fish are not directly linked to survival and are only one component of habitat that may be required for species success. As such, similar to the salinity changes described above, the effects of turbidity on fish and fish habitat will be explored further in Appendices E (*Fish Population Analyses*) and F (*Habitat Restoration*) to better integrate the multiple factors composing fish habitat and the potential effects of the preliminary proposal.

C.7.1.5 Temperature and Dissolved Oxygen

Some temperature changes are expected to occur in some years in some upstream rivers. However, these changes rarely translate to adverse effects on species, as described below. In-Delta water temperature and DO concentrations are not expected to change in response to the preliminary proposal. Water temperatures and DO in the Delta are affected primarily by atmospheric conditions (air temperature, winds, solar radiation, and climate change). Water temperatures are typically in thermal equilibrium with the atmospheric conditions and therefore are not influenced strongly by changes in river flows affected by proposed project operations. Similarly, DO concentrations in the river channels and bays are typically in equilibrium with atmospheric conditions, and proposed project operations are not anticipated to result in biologically significant changes within the Delta. As a result of these factors, it was concluded that proposed project operations would not result in adverse changes in either water temperatures or DO concentrations n the Delta that would affect the target species. Changes in long-term seasonal water temperatures are anticipated to occur within the Delta, however, in response to future climate changes that are independent of proposed project operations, but that also are expected to result in changes in habitat conditions that could potentially adversely affect the population dynamics of the covered species in the future (LLT climate changes).

C.7.2 Flow-Related Biological Effects

The following information is summarized in Table C.1-3, Table C.1-4, and Table C.1-5 above, and describes in detail the conclusions for each species for flow-related parameters in upstream and Delta areas, and for passage, migration, and movement.

C.7.2.1 Upstream Spawning and Egg Incubation

Conclusion 1. Except for Sacramento River spring-run Chinook salmon and Feather River green sturgeon egg incubation, the preliminary proposal would not result in adverse effects on upstream spawning.

Overall, there would be minimal changes to upstream flows and as such, very few effects on spawning and egg incubation. Most of the differences and associated effects on spawning and egg incubation habitat observed among the modeled scenarios were attributable to near-term and long-term climate change effects. In many instances, increased steelhead, winter-run, Pacific lamprey, and river lamprey egg mortality under future conditions is primarily a result of natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on incubating eggs that were largely independent of preliminary proposal operations. Decreased temperatures during egg incubation periods for spring-run Chinook salmon on the Sacramento River and green sturgeon on the Feather River would result in adverse effects on these species.

Steelhead. No adverse effects were detected on steelhead spawning and egg incubation habitat conditions based on CALSIM, SacEFT, and water temperature modeling results. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of spawning and incubation habitat under proposed project and future baseline conditions were comparable. Based on the results, preliminary proposal operations likely would have small annual effects on flows and water temperatures during the steelhead spawning and incubation period, but would not affect long-term habitat conditions relative to future baseline conditions.

Winter-run Chinook salmon. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) for Sacramento River winter-run Chinook salmon based on results from the Reclamation egg mortality model, SacEFT, SALMOD, and other tools. Positive and negative changes in instream flows that affect habitat quality and quantity, such as reduced summer and fall flows relative to existing conditions, were detected in the Sacramento River. Differences in flow in the Sacramento River in September of wetter years between existing and preliminary proposal operations reflect, in large part, differences in fall operations for downstream low-salinity habitat that was included as an operating criterion under the EBC2 conditions but was not included in preliminary proposal operations.

Spring-run Chinook salmon. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) in the Feather River, Trinity River, San Joaquin River, or Clear Creek for spring-run Chinook salmon based on results from the Reclamation egg mortality model, SALMOD, CALSIM outputs, and other tools. Most spring-run Chinook salmon spawn in tributaries such as the Feather River and Mill, Deer, Butte, and Clear Creeks, in which spring-run egg mortality would not be affected by preliminary proposal operations.

In the Sacramento River, the egg mortality model indicated that there is a 5–10% increase in egg mortality of spring-run Chinook salmon under preliminary proposal operations relative to existing biological conditions in wet, above normal, and below normal water years. This increase was a result of increased water temperatures during fall months, particularly September. Refinements in reservoir operations and coldwater pool management, including real-time management, which CALSIM cannot model, may reduce this effect, but this has not been evaluated using the hydrologic and water temperature simulation models. However, results of the SacEFT and SALMOD models, which account for flow, temperature, and other variables in the upper Sacramento River, predict that spawning habitat conditions will not be different (SALMOD) or will be improved (SacEFT) under the proposed project compared to existing biological conditions, which is in contrast to the egg mortality model results described above.

Fall-run Chinook salmon. No major adverse effects were detected on upstream spawning or egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) for fall-run Chinook salmon in the Sacramento River based on results of model analyses using the Reclamation egg mortality model, SacEFT, SALMOD, and other tools. Small positive and negative changes were detected in the Sacramento River, such as reduced summer and fall flows relative to existing conditions. No substantive changes in reservoir storage or river flows affecting fall-run Chinook salmon habitat conditions were detected in the Feather, American, San Joaquin, Stanislaus, or Trinity Rivers or Clear Creek. Preliminary proposal operations have no effect on flows or water temperatures in other tributaries, including the Mokelumne, Cosumnes, Merced, and Tuolumne Rivers, or habitats in areas such as Mill, Deer, Butte, and Battle Creeks.

Late fall–run Chinook salmon. No major adverse effects were detected on late fall–run Chinook spawning and egg incubation habitat conditions in the Sacramento River based on CALSIM, SacEFT, SALMOD, and other modeling tools. Although most changes in spawning habitat were attributable to climate change, the SacEFT model indicated that preliminary proposal operations would result in a small incremental reduction (5%) in the number of years with "good" spawning habitat conditions for late fall–run Chinook salmon.

White and green sturgeon. Spawning white sturgeon and their eggs would experience similar flow and water temperature conditions under preliminary proposal operations relative to existing biological conditions. There are small beneficial and adverse effects on spawning and egg incubation habitat conditions, but no major or consistent adverse effects were detected in the Sacramento, Feather, or Stanislaus Rivers. The greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. These major habitat effects were largely independent of differences between existing conditions and preliminary proposal operations. Likewise, no major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., instream flows and water temperatures during egg incubation) in the Sacramento River for green sturgeon based on results from the Reclamation egg mortality model, SacEFT, CALSIM outputs, and other tools. In the Feather River, however, there is a reduction in flows during July and August of 29% on average, but this effect does not translate into a consistent adverse effect on green sturgeon based on water temperature exposure. There were no meaningful differences between existing biological conditions and preliminary proposal operations in exceedance of water temperature tolerances of 63°F and 68°F. The only effect is an increase of exposure to the upper threshold of green sturgeon tolerance of 73°F in up to 8% more months under preliminary proposal operations compared to existing biological conditions.

Pacific and river lamprey. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) for Pacific lamprey and river lamprey based on results from the Reclamation egg mortality model, CALSIM, and other tools.

C.7.2.2 Holding Flows

Holding flows were evaluated for spring- and winter-run Chinook salmon adults. As described below, no adverse effects of the preliminary proposal are expected.

Conclusion 2. The preliminary proposal would have no effects on spring- or winter-run Chinook salmon adult holding flows.

No major or consistent adverse effects were detected on upstream adult holding habitat conditions (e.g., instream flows) in the Sacramento River for spring- and winter-run Chinook salmon or in the Feather and Trinity Rivers or Clear Creek for spring-run Chinook salmon based on results from CALSIM. The greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. Increased adverse conditions reflect natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on holding adults that were largely independent of preliminary proposal operations.

C.7.2.3 Upstream Rearing Habitat

Upstream rearing habitat for covered species would not change substantially, although some increase in Feather River temperature may adversely affect green sturgeon and river lamprey, and a decrease in late fall–run Chinook salmon rearing habitat also may occur. For spring-run Chinook salmon, fall-run Chinook, green sturgeon, white sturgeon, Pacific lamprey, and river lamprey, the greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. Increased adverse conditions reflects natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on rearing habitat that were largely independent of preliminary proposal operations.

Conclusion 3. Upstream rearing habitat for covered species would not change substantially; however, some adverse effects on late fall–run Sacramento River rearing habitat and on green sturgeon and river lamprey rearing habitat as a result of increases in Feather River temperature, and some benefits to winter-run rearing habitat, are expected.

Steelhead. No major adverse effects were detected on steelhead fry/juvenile rearing habitat conditions based on CALSIM, SacEFT, and water temperature modeling results. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of rearing habitat under proposed project and future baseline conditions were comparable. Most of the differences and associated effects on steelhead rearing habitat observed among the modeled scenarios were attributable to near- and long-term climate change effects. Based on the results, preliminary proposal operations likely would have small annual effects on flows and water temperatures affecting steelhead rearing habitat, but would not affect long-term habitat conditions relative to future baseline conditions. In the Sacramento River between the RBDD and Keswick, the SacEFT model indicated that preliminary proposal operations would result in a small incremental increase (5%) in the number of years with “good” rearing habitat conditions for steelhead.

Winter-run Chinook salmon. The SacEFT model predicted that winter-run Chinook salmon fry/juvenile rearing habitat in the Sacramento River would be classified as *good* in 23–26% more years under preliminary proposal operations relative to existing conditions.

Spring-run Chinook salmon. No major or consistent adverse effects were detected on upstream fry/juvenile rearing habitat conditions (e.g., instream flows, water temperature, stranding) in the Feather River, Trinity River, San Joaquin River, or Clear Creek for spring-run Chinook salmon based on results from CALSIM and the Reclamation water temperature model.

Fall-run Chinook salmon. No major or consistent adverse effects were detected on upstream fry/juvenile rearing habitat conditions (e.g., instream flows, water temperature, stranding) in upstream waterways for fall-run Chinook salmon based on results from CALSIM and the Reclamation water temperature model.

Late fall–run Chinook salmon. No adverse effects were detected on late fall–run Chinook fry/juvenile rearing habitat conditions in the Sacramento River based on CALSIM, SALMOD, and water temperature modeling. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of rearing habitat in the Sacramento River under proposed project and future baseline conditions were comparable. Most of the differences and associated effects on late fall–run Chinook salmon rearing habitat observed among the modeled scenarios were attributable to near- and long-term climate change effects. Despite these results, the SacEFT model indicated that preliminary proposal operations would result in an incremental reduction of 14–28% in the number of years with "good" rearing habitat conditions for late fall–run Chinook salmon. However, based on the weight of evidence (SALMOD results, flow, and temperature exceedance analyses), there should be no detectable change in rearing habitat conditions for late fall–run Chinook salmon in the upper Sacramento River.

Green and white sturgeon. No major or consistent adverse effects were detected on upstream larvae/juvenile rearing habitat conditions (e.g., instream flows, water temperature, and stranding) in the Sacramento River or upstream waterways for green or white sturgeon based on results from CALSIM and the Reclamation water temperature model. Additionally, larval and juvenile white sturgeon would experience similar or slightly improved flow and water temperature conditions. Green sturgeon larvae will experience reduced flows in the Feather River from July through September, when flows are reduced by 42% on average in wet, above normal, below normal, and dry water years. However, reduced flows are not expected to translate into water temperature effects in a major or consistent way, except during the LLT implementation period, during which exposure to the upper 73°F water temperature threshold will occur 5–14% more often under preliminary proposal operations than under existing biological conditions.

Pacific and river lamprey. No major or consistent adverse effects were detected on upstream ammocoete rearing habitat conditions (e.g., instream flows, water temperature, stranding) in upstream waterways for Pacific lamprey or in the Sacramento, Trinity, American, and Stanislaus Rivers for river lamprey based on results from CALSIM and the Reclamation water temperature model. In the Feather River below Thermalito Afterbay, there is a small to moderate increase in exposure to elevated water temperatures, although this effect is not observed farther upstream at the Fish Barrier Dam. This increase in exposure to elevated water temperatures is expected to result in a small to moderate increase in mortality of ammocoetes in the region below the Thermalito Bypass.

C.7.2.4 Passage, Migration, and Movement

Passage, migration, and movement were evaluated for upstream and Delta areas for all species. Overall, the results indicate that there will be some improved and some reduced passage as a result of the preliminary proposal.

Conclusion 4. Overall, flows in upstream areas during migration and transport periods for anadromous fish are not substantially changed under the preliminary proposal, with some exceptions.

The great majority of modeled river flow estimates upstream of the Plan Area suggested that, once effects associated with climate change were factored out, average differences in flow between PP and EBC during covered fish species migration and transport periods would be minor (Table C.1-3). The general pattern was for little change, with minor increases or decreases depending on water-year type. There were essentially no changes in migration flows in Clear Creek, the Stanislaus River, and the San Joaquin River at Vernalis. Analyses were based on the assumption that migration and transport are enhanced with increased flows, although there were few specific thresholds or ranges that could be applied. Summaries of the main patterns are provided below.

Steelhead. The Feather River was the only location where migration flows during periods of steelhead occurrence exhibited a number of differences between preliminary proposal and existing conditions: migration flows for juveniles and kelts were somewhat (generally 10% or more) greater under the preliminary proposal in most water-year types, but for adults, preliminary proposal flows were greater (10–20% more) only in dry and critical years.

Winter-run Chinook salmon. The analysis suggested little difference between existing conditions and preliminary proposal average flows during the juvenile downstream migration period in the upper Sacramento River (River Mile [RM] 194 to Keswick).

Spring-run Chinook salmon. As with steelhead, the Feather River was the only location with appreciable differences in migration flows between preliminary proposal and existing conditions, with the former averaging 5–30% greater than the latter in most water-year types.

Fall-run/late fall–run Chinook salmon. Migration flows for fall-run Chinook salmon were generally little different between preliminary proposal and existing conditions at most locations, except the Sacramento River (RM 194 to Keswick), American River, and Feather River. In the upper Sacramento River, adult migration flows were around 10–20% less under the preliminary proposal in wet and above normal water years, and either similar or up to 20% greater under the preliminary proposal in the remaining water-year types. In the American River, appreciably less average adult migration flow (7–26%) occurred under preliminary proposal conditions than under existing conditions in wet and above normal years, whereas in critical years preliminary proposal flows were 13–39% greater. Juvenile migration flows in the Feather River averaged around 10–20% greater than existing biological conditions for above normal, below normal, and dry years and were similar in other years. Adult migration flows were 12–32% less on average under the preliminary proposal in wet, above normal, and below normal years, in contrast to a similar percentage greater under the preliminary proposal in critical years. For late fall–run Chinook salmon adults, there was little difference in migration flows between the preliminary proposal and existing conditions in the Sacramento River (RM 194 to Keswick).

White sturgeon. Analyses for white sturgeon focused on the Sacramento River (North Delta to RM 143 subregion—i.e., Wilkins Slough and Verona CALSIM nodes). For juveniles, average migration flows at Verona were more than 5% lower under the preliminary proposal scenarios in all water-year types, ranging from around 6–11% in critical years to 20% in wet years. Larval transport flows were represented by the average number of months per year that exceeded thresholds of 17,700 cfs (Wilkins Slough) and 31,000 cfs (Verona) and were variable in terms of estimated effects. The results ranged from little change or somewhat more frequent exceedances of flow thresholds (16% greater in above normal years) under the preliminary proposal relative to existing conditions at Wilkins Slough, to reduced flow threshold exceedances at Verona of 9–50%. (The latter value occurred in dry years, when the average number of months exceeding the threshold was low regardless of scenario.)

Green sturgeon. Flows for green sturgeon migration were analyzed in the upper Sacramento River and Feather River and demonstrated contrasting changes for different life stages. Preliminary proposal flows that were lower than flows under the existing conditions were evident for larvae and juveniles in both systems and occurred primarily in wet, above normal, and below normal years, with the preliminary proposal flows in the Feather River falling in the 25–50% reduction category on average and those in the Sacramento River falling in the 5–25% reduction category. In contrast, adult migration flows were either similar or, in the case of the Feather River, somewhat increased in above normal, below normal, and dry water years.

Pacific lamprey. Average flows during Pacific lamprey migration periods were quite similar under the preliminary proposal and existing conditions (or slightly greater, up to 10%, under the preliminary proposal) on the Sacramento River (RM 194 to Keswick), Feather River, American River, Stanislaus River, and San Joaquin River at Vernalis.

River lamprey. Average flows during river lamprey migration periods generally were quite similar under the preliminary proposal and existing conditions for macropthalmia, with differences occurring for adults that typically indicated lower flows under the preliminary proposal than existing conditions. For adults, the difference was less than 5% for the Stanislaus River and San Joaquin River at Vernalis, whereas flows were 6–13% lower under the preliminary proposal for the Sacramento River (RM 194 to Keswick), Feather River, and American River.

Conclusion 5. Attraction flows and olfactory cues in the west Delta for upstream anadromous migrating fish will be altered because of shifts in exports from the south Delta to the north Delta under the preliminary proposal.

Sacramento River flows downstream of the north Delta intakes will be reduced under preliminary proposal operations relative to existing conditions, while reduced exports in the south Delta generally will increase the proportion of water in the west Delta originating from the San Joaquin River. The change in olfactory cues (percentage of Sacramento River or San Joaquin River water at Collinsville predicted using DSM2 modeling within the fingerprint analysis) differed by species (Table C.1-3). Under the preliminary proposal, the average percentage of Sacramento River–origin water was always lower than for the existing conditions, ranging from 2–4% less for steelhead to 8–10% less for fall-run Chinook salmon. Under the preliminary proposal, the percentage of San Joaquin water was generally considerably greater than under existing conditions, at least in relative terms; however, the actual percentages involved were low (single digits) because a very low percentage of San Joaquin River water contributes to the water in the west Delta in any scenario.

Adult attraction/migration flows at Rio Vista under the preliminary proposal were lower than flows under existing conditions for most water-year types. The relative difference between scenarios ranged from 5–9% in all except critical water years (little changed) for winter-run and late fall–run Chinook salmon to more than 20% in some water-year types for steelhead, spring-run Chinook salmon, and fall-run Chinook salmon; the latter species had up to around 50–60% lower average flows under the preliminary proposal in wet and above normal years. In dry and critical years, differences in migration flows between preliminary proposal and existing conditions were often less than 5%, and in some cases preliminary proposal flows were greater (e.g., fall-run Chinook salmon in the LLT).

Conclusion 6. The preliminary proposal improvements in fish passage facilities at the Fremont Weir and within the Yolo Bypass (CM 2) will reduce delay and stranding of upstream migrating adult anadromous covered fish species.

The suite of actions proposed to improve adult fish passage as part of CM 2 (Yolo Bypass Fisheries Enhancements) is expected to benefit covered fish species by reducing stranding and delay in the Yolo Bypass. Limited stranding and rescue data indicate that appreciable percentages (10% or more) of the green sturgeon spawning population in particular currently may be negatively affected by the passage impediment caused by the Fremont Weir. The efficacy of the passage improvements at the Fremont Weir and other locations in the Yolo Bypass (e.g., Lisbon Weir) cannot be estimated, but will be monitored, and adjustments will be made through adaptive management. Resulting, improvements in migration may vary by year type as a result of differing inundation frequencies and volumes, but overall CM 2 is expected to have a major positive effect on upstream migrating anadromous covered fish species, in particular sturgeons and salmonids.

Conclusion 7. Chinook salmon smolt survival during outmigration through the Delta includes tradeoffs between positive and negative flow changes in the Yolo Bypass and Sacramento River, with uncertainty to be informed by monitoring and adaptive management.

The results of the DPM showed that through-Delta survival of Chinook salmon smolts was generally similar or slightly lower under the preliminary proposal than under existing biological conditions. The difference in survival between preliminary proposal scenarios and existing biological conditions in the early and late long-term ranged from averages of considerably less than 1% of the smolts entering the Delta (San Joaquin–origin fall-run Chinook) to 1–2% of smolts for fall-, spring-, and winter-run Chinook from the Sacramento River and fall-run Chinook from the Mokelumne River. The observed patterns represented tradeoffs between positive and negative aspects of the preliminary proposal relative to the existing biological conditions, as assumed in the model. Positive aspects of the preliminary proposal include the increased diversion of fish into the Yolo Bypass for smolts migrating down the Sacramento River that encounter the new notch at the Fremont Weir. The Yolo Bypass migration route is assumed to have survival equal to the maximum survival in the nearby Sacramento River, as well as offering the advantage of avoidance of diversion through Georgiana Slough or the DCC into the low-survival interior Delta. The benefits of increased entry into the Yolo Bypass were greatest for winter-run Chinook, followed by spring-run and finally fall-run, for which there was little benefit because their assumed timing is during a period when Yolo Bypass inundation is generally too low to promote appreciable diversion. The relatively good survival assumed through the Yolo Bypass is based on studies conducted on fish smaller than smolts, and the assumption will require refinement based on monitoring studies of acoustically tagged smolts to be conducted in the future. Reductions in south Delta exports also improve survival of smolts, although as noted in the entrainment appendix (Appendix B), there are situations in drier water years where exports from the south Delta are increased because of bypass requirements at the north Delta intakes. Such situations generally arise during the fall-run migration period and explain the lower survival through the interior Delta of this race.

Negative aspects of the preliminary proposal include an assumed increase in predation of Sacramento River–origin smolts in the vicinity of the north Delta intake structures because of predators holding station in the area; the current modeling assumed around 1% of each run would be lost, but again this number is uncertain and will be refined through targeted studies. The potential benefits of habitat restoration in the Delta also are not captured by the DPM results, which focus on flow-related survival and migration routes through the Delta.

Conclusion 8. Increase in Stockton Deep Water Ship Channel DO levels (CM 14) will improve upstream migration conditions for fall-run Chinook salmon, steelhead, and other species in the San Joaquin River basin.

Preliminary results from the oxygen diffusion system that forms the basis for CM 14 suggest that it can raise DO levels to meet total maximum daily load objectives (at least 6 mg/L of DO from September 1 to November 30, and at least 5 mg/L at all times). The long-term funding for operations and maintenance of this facility, coupled with improvements that would be implemented based on adaptive management and monitoring, will ensure that any passage impediments caused by low DO in this area for upstream migrating adult fall-run Chinook salmon and steelhead in the San Joaquin River basin would be minimized. Improvement of DO in the vicinity of the ship channel also will benefit any other covered fish species using that area of the Delta.

Conclusion 9. Modification of the Suisun Marsh Salinity Control Gate operation will improve or maintain passage for adult anadromous fish.

As operations of the SMSCG become less frequent, upstream passage for adult anadromous fish such as Chinook salmon, steelhead, sturgeons, and lampreys will have less potential for delay and subsequent effects on reproduction in natal tributaries. Passage will be improved or maintained at low levels expected from reduced operations under the preliminary proposal.

Conclusion 10. Nonphysical fish barriers (CM 16) have the potential to inhibit juvenile fish from entering the interior Delta, but further research is necessary to evaluate effectiveness; unintended passage impedance for adults also requires research.

Juvenile Chinook salmon and steelhead, and juvenile and adult delta smelt, longfin smelt, and Sacramento splittail are most likely to benefit from nonphysical barriers at important channel divergences such as Sacramento River–Georgiana Slough and San Joaquin River–Old River because these species have hearing abilities that are likely to respond to the main barrier stimulus (i.e., the acoustic signal). As such, these barriers could be an effective tool for precluding these species from entering the interior Delta, where mortality may be higher than in the main channels of the Sacramento and San Joaquin Rivers. There is little potential to inhibit white and green sturgeon or Pacific and river lamprey from entering the interior Delta because these species have little sensitivity to the acoustic deterrence of the nonphysical barriers; further, in the case of deep channels, the barriers are not constructed to include the channel bottom area where benthic-oriented species like sturgeon would be migrating. The effectiveness of nonphysical barriers will depend on the water-velocity characteristics in the vicinity of the barrier and on the extent to which predatory fish congregate along the barrier.

However, nonphysical barriers could be encountered by upstream migrating adult anadromous fishes (e.g., winter- and spring-run Chinook salmon, steelhead, Sacramento splittail, sturgeons, and lampreys). The potential for impedance or delay would be low for fish with poor hearing ability (sturgeons and lampreys), whereas the potential for impedance of the other species would increase as water depth decreases and a greater portion of the water column is occupied by the barrier. Ongoing testing at Georgiana Slough and the head of the Old River will provide more insight into the potential effectiveness of CM 16 under various flow and geomorphic conditions, as will monitoring, research, and adaptive management of the CM.

Conclusion 11. Reduced Sacramento River flows may reduce longfin smelt and delta smelt larval transport, with the potential to reduce survival for longfin smelt.

Decreased transport flows in the lower Sacramento River have been identified as one mechanism that could adversely affect the growth and survival of larval delta and longfin smelt. Compared to existing biological conditions, the preliminary proposal reduces Delta outflows during the winter-spring delta smelt and longfin smelt larval period, potentially reducing downstream longfin larval transport and subsequent survival. Projected reductions assume a direct relationship between outflow (expressed as X2) and longfin smelt abundance. However, the correlation is not understood, and it may not reflect larval transport but may instead be reflective of some other relationship. The longfin smelt analysis estimated that once climate change–related flow effects had been factored out, changes in outflow during the larval period have the potential to reduce abundance of older life stages represented in Bay-Delta trawl surveys by 8–24% in the ELT and 1–18% in the LLT on average. Results of particle tracking modeling for longfin smelt estimated that the potential for emigration to the LSZ in Suisun Bay (as represented by the number of particles reaching Martinez) was on average 0–8% lower under the preliminary proposal compared with existing biological conditions when accounting for climate change–related effects.

For delta smelt, larval transport under the preliminary proposal as assessed by particle tracking ranged from little difference from existing conditions up to 20% less, after accounting for flow-related climate change effects. In contrast to longfin smelt, relationships estimating subsequent abundance of older life stages from changes in transport flows are not present, so the estimated changes solely reflect changed potential in larval transport.

C.7.2.5 Delta Area Effects

Conclusion 12. Changes in Sacramento River flow may result in an overall decrease in channel margin bench habitat, but restoration will offset this effect.

Results of the analysis of the effects of changes in Sacramento River flow and water surface elevation on channel margin bench habitat showed site-specific differences attributable to site elevation and the interplay of differing flows and other effects such as tidal muting from the preliminary proposal. At the north Delta sites, inundation frequency under the preliminary proposal was on average similar to or lower than under existing conditions, whereas average inundation duration was lower in the early long-term and higher in the late long-term. At the Cache Slough site, considerable increases in inundation frequency and duration under the preliminary proposal may be a result of the site's low elevation combining with tidal dampening because of restoration. Reductions in bench habitat inundation at existing sites may be offset by restoration at other sites within the North Delta and Cache Slough subregions, as described for CM 4 (Tidal Habitat Restoration) and analyzed in Appendix F, *Habitat Restoration*.

Conclusion 13. The reduction in OMR reverse flows and the corresponding increase in net positive downstream flows through the south Delta channels are expected to improve migration cues, improve migration rates and pathways, and contribute to improved larval and juvenile survival and reduced adult straying; reverse OMR flows will be greater in certain water-year types.

As a result of preliminary proposal operations, the frequency and magnitude of OMR reverse flows are expected to be reduced significantly during the late winter and spring period for wet, above normal, and critical years, which coincides with the seasonal period of migration of many of the juvenile fish such as Chinook salmon, steelhead, larval and juvenile delta and longfin smelt, and juvenile splittail through the interior Delta channels. The predicted improvements in south Delta flow conditions (significantly reduced OMR reverse flows, improved net positive downstream flows, improved olfactory cues, and attraction flows for the San Joaquin River and its tributaries) are significant benefits of the PP operations on flow conditions affecting habitat, migration, and survival of fish inhabiting the Delta.

Improved hydrologic conditions in the south Delta in response to proposed project operations are expected to contribute to improvement in the flow cues followed by juvenile and adult fish passing upstream and downstream through the Delta and thereby improve migration and survival and reduce straying. Reduction in OMR reverse flows also is expected to reduce the movement of planktonic larval and juvenile fish (e.g., delta and longfin smelt, Chinook salmon) from the

Sacramento River through the interior Delta to the south Delta and thereby improve their survival and abundance. However, as noted in Appendix B (*Entrainment*), OMR reverse flows may be increased in the late winter/spring in drier water-year types because of export restrictions at the north Delta intakes, which would negatively affect species present there at the time, such as juvenile spring-run Chinook salmon and larval-juvenile delta smelt.

In dry and below normal water years, the reverse OMR flows are increased compared to existing biological conditions, which may translate to adverse effects on Chinook salmon and splittail juveniles, and delta smelt and longfin smelt larvae and juveniles. However, the reverse OMR flows under the preliminary proposal for all water years are still within the requirements of the NMFS and USFWS BiOps for CVP and SWP operations, and the biological response of these species to relatively small OMR reverse flow changes may not result in adverse changes in species survival.

Conclusion 14. Increased Yolo Bypass inundation will create substantial biological benefits to Sacramento splittail spawning and rearing, with other species likely to benefit; stranding risk is generally low.

Based on results of hydrologic models, modification to the Fremont Weir to increase inundation of the Yolo Bypass floodplain during the winter and spring months (CM 2) would create substantial biological benefits to splittail spawning success and rearing; increased benefits to rearing and migration by other juvenile and adult fish also are expected. The benefits of enhanced growth for Chinook salmon fry on the Yolo Bypass are examined in Appendix F, *Ecological Effects*. The benefits of increased inundation to splittail were found to be greatest in wet, above normal, and below normal water years, when seasonal flows in the Sacramento River are greatest. In these water-year types, habitat area for splittail was on average 60–300% greater under the preliminary proposal scenarios compared to existing biological conditions. The anticipated benefits would be greatest for those fish that rear in floodplain habitats as juveniles during downstream migration, including juvenile winter- and fall-run Chinook salmon. Other fish such as steelhead, late fall–run Chinook salmon, green and white sturgeon, and Pacific lamprey would be expected to benefit from using the flooded bypass as a migratory corridor, but would not be expected to rear extensively in the flooded area. Splittail, which spawn on seasonally inundated floodplain habitat, would be expected to benefit from access to spawning and juvenile rearing floodplain habitat. There is little or no change in inundation of the Yolo Bypass floodplain in dry and critically dry years when river flows are low.

Fish species such as splittail and juvenile Chinook salmon that historically used seasonally inundated floodplain habitat for spawning or juvenile rearing have adapted behavior to respond to flow recessions and draining of floodplain habitat. The DRERIP analysis of stranding suggested low magnitude of negative effect for all species examined other than juvenile steelhead, for which the potential for stranding was assessed to be slightly higher. In general, the risk of stranding juvenile fish in the Yolo Bypass has not been identified as a major potential source of mortality but will be informed by monitoring and adaptive management of improvements to the floodplain.

Conclusion 15. The delta smelt fall abiotic habitat index is estimated to be similar between the preliminary proposal and existing biological conditions in the drier 40–50% of years and will be lower under the preliminary proposal in the wetter 50–60% of years, with the magnitude of difference depending on existing biological conditions; if occupied by delta smelt, restored habitat may decrease the magnitude of difference in wetter years and result in a greater habitat index in drier years.[5]

The delta smelt fall abiotic habitat index was lower under the preliminary proposal relative to existing biological conditions, particularly for years with higher flow (Table C.1-3). The greatest differences were for years with higher flow under the EBC2 scenarios, which incorporated the USFWS (2008) BiOp requirements for Fall X2 in above normal and wet years. The differences were relatively low between EBC1 and preliminary proposal scenarios because the requirements for Fall X2 were not included under the modeling for EBC1. Under the assumption that restored areas have abiotic characteristics similar to adjacent areas, the magnitude of the reductions under the preliminary proposal may be reduced in wetter years, and there may be a similar or greater habitat index in drier years (Table C.1-3). However, this assumption will depend on the characteristics in the ROAs, a topic explored in more detail in Appendix E (Habitat Restoration). The likely change in the X2–abiotic habitat index relationship under future configurations of the Delta and the potential influence of additional factors such as water temperature add uncertainty to potential effects. Monitoring in restored areas will provide information on physicochemical characteristics of the new habitat to inform the nature of changes in the delta smelt fall habitat index. Fish sampling in these new areas also will reveal the actual extent to which the areas are used by delta smelt.

5 The scientific value of the abiotic habitat method and its application is currently the subject of Endangered Species Act litigation between USFWS, DWR and the public water agencies, has been under scientific review, and is the subject of ongoing data collection and evaluation. The utility of the results of this method, along with other methods used to evaluate delta smelt habitat, will be reported in Chapter 5.